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10 R. K. Dumbauld H. E. Cramer

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H. E. Cramer Company, Inc.
P. O. Box 8049
Salt Lake City, Utah 84108

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This technical report describes the use of dispersion model to calculate aerosolization ef losses of wastewater aerosols generated by spra wastewater. Field measurements of biological a this study were made by the U. S. Army Medical Development Laboratory (USAMBRDL) at Ft. Huachu by USAMBRDL and the U. S. Army Corps of Enginee

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(25 trials).

The geometric mean aerosolization efficiency for standard plate count for all the trials analyzed in this study is 1.98 x 10^{-3}. The geometric mean aerosolization efficiency for Coliforms determined by the spread plate method on Endo agar is 5.64 x ~~10^{-4}~~ and for Coliforms determined by the membrane filter method using m-Endo broth is 2.26 x 10^{-3}. The geometric mean aerosolization efficiency for Coliphage F2 is 4.44 x ~~10^{-4}~~ compared to a value of 8.10x~~10^{-3}~~ for the dye on all trials analyzed in this study. These aerosolization efficiency estimates lead to the following estimates of the viability losses of the biological aerosols: 76 percent for standard plate count; 93 percent for Coliforms determined by the membrane filter method using m-Endo broth, and 95 percent for Coliphage F2. USAMBRDL will use the results of this study to assist in establishing design and operational criteria for land application and in developing data for environmental impact statements.

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CALCULATED AEROSOLIZATION EFFICIENCIES FOR THE DEER CREEK LAKE AND THE 1974 AND 1975 FT. HUACHUCA SPRAY TRIALS

FINAL REPORT

R. K. DUMBAULD
H. E. CRAMER

FEBRUARY 1978

Supported by

U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21701

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H. E. Cramer Company, Inc.
P. O. Box 8049
Salt Lake City, Utah 84108

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EXECUTIVE SUMMARY

The study described in this report is part of an overall effort to assess hazards to human health and the environment from application of domestic wastewater to land at military installations. The findings of these studies will be used in establishing design and operational criteria for land application and in developing data for environmental impact statements.

As a part of this effort, the potential for dispersion of microbial pathogens via aerosols generated by spray irrigation with treated wastewater is being studied by the U. S. Army Medical Bioengineering Research and Development Laboratory (USAMBRDL). Microbiological aerosol studies have been conducted at field sites during actual application of both chlorinated and unchlorinated treated domestic wastewater. Sampling data were obtained on aerosol particle size profiles and downwind aerosol dispersion.

This report describes the use of a predictive mathematical dispersion model to calculate aerosolization efficiencies of wastewater aerosols released during a two-phase study conducted by USAMBRDL at Ft. Huachuca, Arizona (1974-75) and during the study jointly conducted at Deer Creek Lake, Ohio in the summer of 1976 by USAMBRDL and the U. S. Army Corps of Engineers. The field trials at Ft. Huachuca were conducted at the base golf course driving range which is irrigated with secondary treated wastewater using Rain Bird® sprinklers. Sixteen trials were conducted during the fall of 1974 and seventeen trials were conducted in 1975. Measurements of bacterial aerosols were made downwind from a simple sprinkler head in all but two of the trials using seven Andersen® viable-type samplers. In addition, from one to three large volume electrostatic precipitation-type samplers were used in each trial. Aerosol samples were collected at 13 sampling locations downwind from a large spray irrigation field during 25 field trials at Deer Dreek Lake. The irrigation field contained 96 Rain Bird® sprinklers. A dye tracer was added to the spray irrigation water for some trials at both Ft. Huachuca and Deer Creek Lake to assist in determining the viability loss of aerosols as compared to an inert material.

Aerosolization efficiency is defined by the ratio of the concentration measured at a sampling station to the concentration calculated at the station by the predictive model under the assumption that there are no losses of aerosol during the aerosolization process, by gravitational settling or other removal process or by decay. The viability loss of biological aerosols is calculated by comparing the aerosolization efficiencies of biological aerosols with those of the inert dye tracer aerosol. In this study, a volume source dispersion model computer program was used to predict the biological and dye tracer concen-

trations at the sampler stations and to produce plots of predicted concentration isopleths downwind from the sprinklers. Meteorological and source parameters measured during the field experiments were used to develop model inputs. Aerosolization efficiencies were calculated for each type of biological aerosol sampled and for the dye samplers. The geometric mean aerosolization efficiency for standard plate count for all the trials analyzed in this study is 1.98×10^{-3}. The geometric mean aerosolization efficiency for Coliforms determined by the spread plate method on Endo agar is 5.64×10^{-4} and for Coliforms determined by the membrane filter method using m-Endo broth is 2.26×10^{-3}. The geometric mean aerosolization efficiency for Coliphage F2 is 4.44×10^{-4} and for the dye on all trials analyzed in this study is 8.10×10^{-3}. These aerosolization efficiency estimates lead to the following estimates of the viability losses of the biological aerosols: 76 percent for standard plate count; 93 percent for Coliforms determined by the spread plate on Endo agar, 72 percent for Coliforms determined by the membrane filter method using m-Endo broth, and 95 percent for Coliphage F2.

Results of the study described in this report will be used in an executive summary report to be prepared under contract to the U. S. Army Medical Research and Development Command by Southwest Research Institute (SwRI), San Antonio, Texas. The SwRI report will incorporate the results of this study with the contract study performed by SwRI at Pleasanton, California during 1975 and 1976.

FOREWORD

This final report is submitted to the U. S. Army Medical Bioengineering Research and Development Laboratory (USAMBRDL), Fort Detrick, Maryland in fulfillment of requirements under Contract No. DAMD 17-77-C-7048.

The H. E. Cramer Company, Inc. is indebted to Dr. Howard Bausum, USAMBRDL, for the technical guidance and very helpful suggestions he provided during the course of the contract and in the preparation of this report.

TABLE OF CONTENTS

LIST OF APPENDIXES

LIST OF FIGURES

LIST OF TABLES

SECTION 1

INTRODUCTION

1.1 BACKGROUND

The U. S. Army Medical Research and Development Command has been conducting a program to assess the potential health hazard from pathogenic aerosols which may be released during wastewater spray irrigation. As part of this program, the U. S. Army Medical Bioengineering Research and Development Laboratory (USAMBRDL) conducted field trials at Ft. Huachuca, Arizona in the fall of 1974 and 1975 to determine the aerosolization efficiency of bacterial and tracer aerosols downwind from wastewater spray irrigation equipment. A field study was also conducted jointly be USAMBRDL with the U. S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (USACRREL) at Deer Creek Lake, Ohio in the summer of 1976.

During the 25 field trials at Deer Creek Lake, aerosol samples were collected at 13 sampling locations downwind from a large spray irrigation field containing 96 Rain Bird® spray nozzles, each delivering 5 gallons per minute of spray irrigation water. Nozzle internal diameter was 5/32 in. (0.79 cm) and nozzle pressure was 56-59 psi. The schematic diagram in Figure 1-1 shows the spray irrigation field and sampler positions for Trials 1 through 4, which is typical of the sampling layout used in all the trials. Replicate samplers at the three measurement distances of 20, 40 and 206 meters downwind from the last row of sprinklers are individually separated by a distance of three meters.

The field trials at Ft. Huachuca were conducted at the base golf course driving range which is irrigated with secondary treated wastewater using Rain Bird® sprinklers, each delivering 110 gallons per minute. Nozzle internal diameter was 0.5 in. (1.3 cm) and nozzle pressure was 95-100 psi. Sixteen trials were conducted during the fall of 1974 and seventeen trials were conducted in 1975. All but two of the trials and all the trials analyzed in this report were conducted with only one sprinkler in operation. Seven samplers were used to collect aerosol samples in the Ft. Huachuca trials. Because of unpredictable variations in wind direction, fewer than seven positive samples (microbiological samples above background) were obtained in many of the Ft. Huachuca trials. Measurements of bacterial aerosols were made using Andersen® viable-type samplers. In addition, from one to three large-volume electrostatic precipitation samplers (LEAP® or Litton Type M®) were used in each trial and positioned at different distances. In tracer trials, the Andersen samplers were replaced by all-glass impingers.

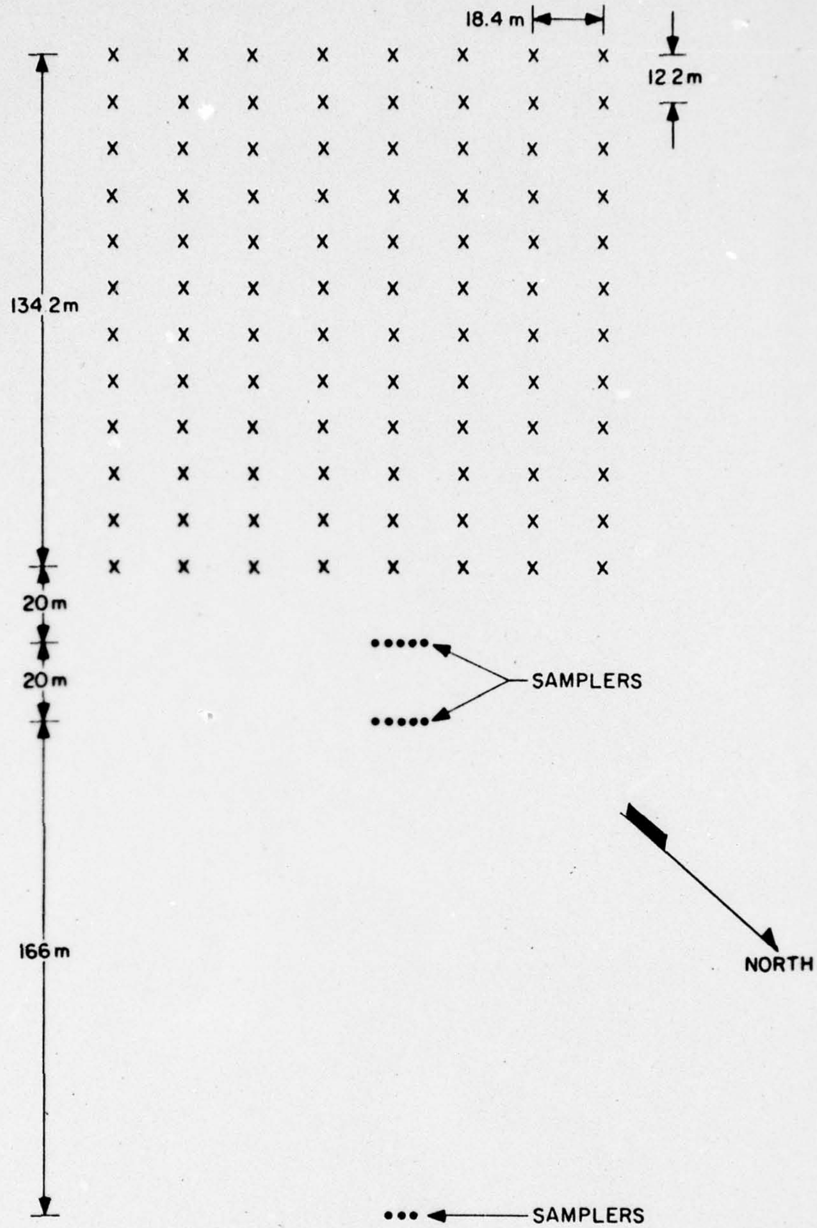

FIGURE 1-1. Schematic diagram showing spray irrigation field and sampler positions for Trials 1 through 4 of the Deer Creek Lake trials. Sampler rows were oriented perpendicular to the anticipated mean wind direction. Additional samplers (not shown) were located upwind to measure background.

Details of the 1974 sampling program at Ft. Huachuca are contained in a report by Bausum, _et al_., 1976[1] and by Sorber, _et al_., 1976[2]. Details of the 1975 Ft. Huachuca trials will be contained in a forthcoming report by USAMBRDL (Bausum, _et al_., 1978)[3]. A joint report is under preparation by USAMBRDL and USACRREL describing details of the Deer Creek Lake Trials (Bausum, _et al_., 1978)[4].

1.2 STUDY OBJECTIVES

The primary objectives of the sampling program and overall study effort are to determine the aerosolization efficiency and the depletion by decay and air shock of bacterial aerosol clouds generated by wastewater spray systems. These parameters can be estimated by comparing the aerosol sampling results with model concentrations calculated under the assumption that no losses occur, (i.e., that all of the microorganisms contained in the wastewater are aerosolized and carried downwind without depletion by gravitational settling, decay or air shock). A second objective of the program is to characterize the generation and dispersion of the plumes generated by wastewater spray systems. Appropriate models have been developed by the H. E. Cramer Company for the U. S. Army and have been used in estimating aerosolization efficiencies for wastewater trials conducted at Pleasanton, California (Anderson, 1976[5], 1977[6]). Consequently, USAMBRDL requested these models and calculation procedures be used to analyze the Deer Creek Lake and Ft. Huachuca data so that a direct comparison could be made with the results of the Pleasanton trials. Specifically, under Contract DAMD 17-77-C-7048, the H. E. Cramer Company agreed to provide USAMBRDL with:

- Atmospheric dispersion-model calculations of aerosol concentrations at all sampling positions for each of the 25 trials conducted at Deer Creek Lake and for a minimum of 12 trials conducted at Ft. Huachuca

- Computer plots of calculated normalized aerosol concentration isopleths for each trial for which model calculations are made

- Aerosolization efficiencies for each sampling position, obtained by forming ratios of measured and calculated aerosol concentrations at all sampling positions

This technical report describes the predictive model used in performing the requisite concentration calculations, the inputs used in the calculations, and the results of the calculations as prescribed in the contract.

1.3 REPORT ORGANIZATION

Section 2 of this report contains a description of the predictive dispersion model used in the concentration calculations. Source and meteorological model inputs derived from the trial data supplied by USAMBRDL are given in Section 3. The results of the calculations are summarized in Section 4. There are six appendices to the report containing detailed results of the study. Appendices A, B and C contain tables of the measured and calculated concentrations as well as the calculated aerosolization efficiencies for the Deer Creek Lake trials, the 1974 Ft. Huachuca trials and the 1975 Ft. Huachuca trials. Isopleth plots of calculated counts of viable organisms for the Deer Creek Lake trials are contained in Appendix D. Appendices E and F respectively contain isopleth plots of calculated concentration for the 1974 and 1975 Ft. Huachuca trials. The isopleths in Appendices E and F were calculated for a unit source strength. Concentrations for the various bacteria sampled during the Ft. Huachuca trials can be obtained by multiplying the isopleth values by the source emission rate for each type of organism.

SECTION 2

MATHEMATICAL DISPERSION MODEL USED IN THE CONCENTRATION CALCULATIONS

The mathematical dispersion model used to calculate the aerosol concentrations presented in this report is based on the models and modeling concepts described by Cramer, et al., (1972)[7] and is contained in a computer program (Volume Source Diffusion Models Program) developed by Bjorklund and Dumbauld (1977)[8]. The Volume Source Diffusion Models Program also has the capability of calculating the ground-level deposition of aerosols due to gravitational settling and precipitation scavenging downwind from all types of sources. In calculating the aerosol concentrations in the report, we have used the simplified version of the model described below in which cloud depletion due to deposition and decay is set to zero and it is further assumed that aerosols are totally reflected at the earth's surface. The reference grid used in the computer calculations utilizes a Cartesian coordinate system with the positive x axis increasing in the downwind direction and the y axis oriented crosswind and positive to the right of an observer looking downwind. The basic concentration model refers to a single volume source. For the Deer Creek Lake trials, each sprinkler was treated as a single source and the total aerosol concentration from all sources at a sampler was obtained by summing the contributions from all sprinklers at each point on the reference grid. Because of large changes in wind direction during some trials, each of these trials was subdivided into time periods during which the wind direction remained relatively constant. In these cases, the computer program sums the model contributions over all the time periods to obtain the total aerosol concentration at the sampler position.

The concentration downwind from a continuous volume source under the above assumptions is expressed as the product of three terms:

$$\text{Concentration} = \{\text{Peak Concentration Term}\}\{\text{Vertical Term}\}\{\text{Lateral Term}\} \quad (2\text{-}1)$$

The Peak Concentration Term is defined by the expression

$$\frac{K\,Q}{2\pi\,\sigma_y\,\sigma_z\,\bar{u}} \quad (2\text{-}2)$$

where

K	=	parameter used to convert inputs into dimensionally consistent units
Q	=	source emission rate
σ_y	=	standard deviation of the crosswind distribution of material
σ_z	=	standard deviation of the vertical distribution of material
$\bar{u}$	=	mean wind speed in the layer containing the cloud

The Vertical Term is given by the expression

$$\sum_{a=0}^{\infty}\left[\exp\left[-\frac{1}{2}\left(\frac{2aH_m-H+z}{\sigma_z}\right)^2\right]+\exp\left[-\frac{1}{2}\left(\frac{2aH_m+H+z}{\sigma_z}\right)^2\right]\right]$$

$$+\sum_{a=1}^{\infty}\left[\exp\left[-\frac{1}{2}\left(\frac{2aH_m+H-z}{\sigma_z}\right)^2\right]+\exp\left[-\frac{1}{2}\left(\frac{2aH_m-H-z}{\sigma_z}\right)^2\right]\right] \qquad (2\text{-}3)$$

where

H_m	=	depth of the surface mixing layer
H	=	effective source height
z	=	height above ground

The Lateral Term refers to the crosswind expansion of the cloud and is given by the expression

$$\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \qquad (2\text{-}4)$$

where

y = lateral distance from the cloud centerline

The equations defining the distance dependence of the standard deviations of the crosswind and vertical distributions of material are given below.

The standard deviation of the crosswind distribution of material is given by the expression

$$\sigma_y = \sigma_A'\{\tau\} \; x_{ry} \left[\frac{x + x_y - x_{ry}(1-\alpha)}{\alpha \, x_{ry}} \right]^{\alpha} \tag{2-5}$$

where

x = distance from the source

$\sigma_A'\{\tau\}$ = standard deviation of the azimuth wind angle in radians in the surface mixing layer for the sampling period

x_{ry} = distance over which rectilinear crosswind cloud expansion occurs downwind from a virtual point source

α = crosswind diffusion coefficient

x_y = crosswind virtual distance

$$x_y = \left\{ \begin{array}{ll} \dfrac{\sigma_{yR}}{\sigma_A'\{\tau\}} - x_{Ry} & ; \; \sigma_{yR} \leq \sigma_A'\{\tau\} x_{ry} \\[2em] \alpha \, x_{ry} \left(\dfrac{\sigma_{yR}}{\sigma_A'\{\tau\} \, x_{ry}} \right)^{1/\alpha} - x_{Ry} + x_{ry}(1-\alpha) & ; \; \sigma_{yR} > \sigma_A'\{\tau\} x_{ry} \end{array} \right\} \tag{2-6}$$

σ_{yR} = standard deviation of the crosswind concentration distribution at a distance x_{Ry} downwind from the source

x_{Ry} = lateral reference distance

The standard deviation of the vertical distribution of material is given by the expression

$$\sigma_z = \sigma_E' \, x_{rz} \left[\frac{x + x_z - x_{rz}(1-\beta)}{\beta \, x_{rz}} \right]^{\beta} \tag{2-7}$$

where

σ_E' = standard deviation of the elevation wind angle in radians

x_{rz} = distance over which rectilinear vertical cloud expansion occurs downwind from a virtual point source

β = vertical diffusion coefficient

x_z = vertical virtual distance

$$x_z = \begin{cases} \dfrac{\sigma_{zR}}{\sigma_E'} - x_{Rz} & ; \quad \sigma_{zR} \le \sigma_E' \, x_{rz} \\[2ex] \beta \, x_{rz} \left(\dfrac{\sigma_{zR}}{\sigma_E' \, x_{rz}} \right)^{1/\beta} - x_{Rz} + x_{rz}(1-\beta) & ; \quad \sigma_{zR} > \sigma_E' \, x_{rz} \end{cases} \tag{2-8}$$

σ_{zR} = standard deviation of the vertical concentration distribution at a distance x_{Rz} downwind from the source

x_{Rz} = vertical reference distance

The mean wind speed $\bar{u}$ is defined by the expression

$$\bar{u} = \begin{cases} \dfrac{\bar{u}_R \left(z_2\right)^{1+p} - \left(z_1\right)^{1+p}}{\left(z_2 - z_1\right)\left(z_R\right)^p\left(1+p\right)} & ; \quad \bar{u} > \bar{u}_R \\ \\ \bar{u}_R & ; \quad \bar{u} \leq \bar{u}_R \end{cases} \qquad (2\text{-}9)$$

where

$\bar{u}_R$ = mean wind speed at the reference height z_R

p = wind profile power-law exponent

z_2 = effective upper bound of the cloud

$$= \begin{cases} H + 2.15\,\sigma_z & ; \quad z_2 < H_m \\ \\ H_m & ; \quad z_2 \geq H_m \end{cases} \qquad (2\text{-}10)$$

z_1 = effective lower bound of the cloud

$$= \begin{cases} H - 2.15\,\sigma_z & ; \quad z_1 > 0 \\ \\ 0 & ; \quad z_1 \leq 0 \end{cases} \qquad (2\text{-}11)$$

The source and meteorological input parameters required by model are presented in Table 2-1.

TABLE 2-1

SOURCE AND METEOROLOGICAL MODEL INPUT PARAMETERS

Parameter	Definition	Units
σ_{yR}	Standard deviation of the crosswind concentration distribution at a distance x_{Ry} downwind from the source	Meters
σ_{zR}	Standard deviation of the vertical concentration distribution at a distance x_{Rz} downwind from the source	Meters
x_{ry}	Distance from the virtual point source over which rectilinear expansion in the lateral occurs	Meters
x_{rz}	Distance from the virtual point source over which rectilinear expansion in the vertical occurs	Meters
x_{Ry}	Lateral reference distance	Meters
x_{Rz}	Vertical reference distance	Meters
z_R	Reference height	Meters
α	Crosswind diffusion coefficient	

TABLE 2-1 (Continued)

Parameter	Definition	Units
β	Vertical diffusion coefficient	
σ'_E	Standard deviation of the wind-elevation angle	Radians
$\sigma'_A\{\tau\}$	Standard deviation of the wind-azimuth angle for the sampling period τ	Radians
H_m	Depth of the surface layer	Meters
H	Height of a source above ground level	Meters
$\bar{u}_R$	Wind speed at height z_R	Meters/ Second
p	Wind-speed profile power-law exponent	Fraction
Q	Source emission rate	Amount/ Second
x, y, z	Sampler coordinates	Meters

SECTION 3

SOURCE AND METEOROLOGICAL INPUT PARAMETERS

3.1 DEER CREEK LAKE TRIALS

Table 3-1 and 3-2 show the values assigned to the source input parameters for the Deer Creek Lake trials. The entries in the tables are based on information supplied by USAMBRDL. The source height H in all calculations was set equal to the height above ground of the spray heads (0.6 meters). The lateral and vertical source dimensions assigned to each spray head were determined from visual observations which showed that the spray cone extended about 3.4 meters above the spray head and that the wet area on the ground beneath each spray head was about 26.5 meters in diameter. The parameter values σ_{zR} and σ_{yR} shown in Table 3-1 were respectively obtained by dividing the height of the spray cone above the spray head by 2.15 and the diameter of the wetted area by 4.30. These factors convert the vertical and lateral spray cone dimensions to the standard deviations of a Gaussian bivariate distribution centered on each spray head. In Table 3-1 the distances from the source x_{Rz}, x_{Ry} at which σ_{zR} and σ_{yR} are specified are thus set equal to zero.

Meteorological input parameters for the Deer Creek Lake trials were primarily derived from wind-speed and wind-direction measurements made at heights of 2 and 21 meters on a meteorological tower located near the spray irrigation field. The H. E. Cramer Company was supplied with one-minute averages of wind speed and direction for all of the trials. Mean wind speeds and wind directions, as well as the standard deviation of the wind azimuth angle ($\sigma'_A\{\tau\}$) for the sampling period τ were calculated from these data. The wind-profile exponent p was also calculated from the relationship

$$p = \frac{\ln\left(\frac{\bar{u}\{21 \text{ meters}\}}{\bar{u}\{2 \text{ meters}\}}\right)}{\ln\left(\frac{21 \text{ meters}}{2 \text{ meters}}\right)} \tag{3-1}$$

where $\bar{u}\{2 \text{ meters}\}$ and $\bar{u}\{21 \text{ meters}\}$ are the mean wind speeds measured at 2 and 21 meters. Because measurements of the standard deviation of the wind elevation angle σ'_E were not made, σ'_E was calculated from the relationship

$$\sigma'_E = \sigma'_A \left(\frac{2.5}{\tau}\right)^{1/5} \tag{3-2}$$

where τ is the duration of the sampling period in seconds. This relationship assumes that the vertical and lateral turbulence intensities

TABLE 3-1

SOURCE PARAMETERS FOR THE DEER CREEK TRIALS

Parameter	Value (meters)
σ_{zR}	1.58
σ_{yR}	6.17
x_{Ry}	-0-
x_{Rz}	-0-
H	0.6

TABLE 3-2

SOURCE STRENGTHS FOR THE DEER CREEK LAKE TRIALS*

Trial Number	Source Emission Rate (Q)	
	Biological Trials (colony-forming organisms/minute)	Dye Trials (nanograms per minute)
1	1.00×10^9	
2	3.21×10^8	
3	6.80×10^8	
4	5.48×10^8	
6		5.95×10^7
7	6.43×10^8	
8	6.62×10^8	
9		6.31×10^7
10	1.10×10^8	
11	1.70×10^8	
12	2.84×10^8	
13	1.70×10^8	
14	6.62×10^8	
15	6.62×10^8	
16	3.40×10^8	
17	3.21×10^8	
18		1.15×10^8
19	1.51×10^8	
20	5.86×10^8	
21	5.29×10^8	
22	3.97×10^8	
23		8.75×10^7
24	1.25×10^9	
25	5.48×10^8	

* Source strength data for Trial No. 5 are missing.

are approximately equivalent for 2.5-second sampling periods and that the 1/5 power-law describes the increase of σ_A' with increased sampling period. Values of the meteorological inputs for each trial are given in Table 3-3.

The mixing depth H_m was arbitrarily set to 1000 meters for all the calculations, since the tower measurements and general meteorological observations made at Deer Creek during the trials did not indicate the presence of low-level elevated inversions which would affect dispersion over the sampling distances used in the trials. Note that the selection of 1000 meters for the H_m, combined with the relatively short downwind distances at which concentrations were calculated in this study, results in the use of only the first two terms in Equation (2-3) on page 13 (a=0) in calculating concentrations. Also, the vertical (β) and lateral (α) diffusion coefficients were respectively set equal to 1 and 0.9 for all the calculations and the rectilinear expansion distances x_{ry} and x_{rz} set equal to 50 meters.

3.2 MODEL INPUT PARAMETERS FOR THE 1974 AND 1975 FT. HUACHUCA TRIALS

As noted in Section 1, a single Rain Bird® spray head delivering 110 gallons per minute of irrigation water was used as the source on all the Ft. Huachuca trials studied in this report. Source strength measurements of bacterial or dye levels in the water supplied to the heads were made during each trial. In dye trials, a measured amount of tracer was continuously added to the irrigation water using a peristaltic pump. Source strengths used in the concentration calculations for the 1974 and 1975 Ft. Huachuca trials are respectively given in Tables 3-4 and 3-5. The spray heads were mounted about 0.6 meters above ground level and this height was used for the effective source height H in the calculations. The spray heads for the Ft. Huachuca trials were larger than for the Deer Creek trials, and thus covered a larger effective spray area per head. Source dimensions for the concentration calculations made for the Ft. Huachuca trials were calculated by using procedures similar to those described in Section 3.1 above. The source input parameters for the Ft. Huachuca trials are summarized in Table 3-6.

Meteorological model input parameters were derived primarily from wind measurements made at a height of 2 meters using a mast located in the expected direction of downwind cloud travel. The wind direction was more variable during the trial periods at Ft. Huachuca, which were generally for longer sampling times than those used at Deer Creek Lake. For this reason, the time period for some trials was subdivided into several intervals during which the wind direction was relatively constant, and the mean wind direction, mean wind speed, and value of σ_A' calculated for each period from the one-minute averaged data supplied by USAMBRDL. Estimates of σ_E' were calculated from Equation (3-2). Since wind speed data were available only at a height of 2 meters, the wind

TABLE 3-3

METEOROLOGICAL INPUTS FOR THE DEER CREEK LAKE TRIALS

Trial Number	Sampling Period LST*	Mean Wind Direction (degrees)	Wind Speed @ 2 meters $\bar{u}_R$ (m sec^{-1})	Wind Profile Exponent p	Standard Deviation of the Vertical Wind Direction σ'_E (radians)	Standard Diviation of the Horizontal Wind Direction σ'_A (radians)
1	1207-1227	214	3.8	0.08	0.0419	0.1449
2	1456-1516	212	3.9	0.11	0.0524	0.1815
3	1219-1239	223	3.9	0.12	0.0593	0.2025
4	1626-1646	265	3.6	0.18	0.0803	0.2758
6	1406-1427	263	2.7	0.09	0.0873	0.3002
7	1059-1119	221	4.8	0.15	0.0489	0.1676
8	1348-1408	237	4.6	0.12	0.0454	0.1536
9	2101-2121	208	1.7	0.31	0.0349	0.1222
10	1134-1154	234	3.6	0.12	0.0768	0.2635
11	1207-1227	236	3.0	0.13	0.0750	0.2601
12	1347-1407	211	3.1	0.17	0.0995	0.3438
13	1553-1613	212	3.9	0.19	0.0576	0.1972

*LST - Local Standard Time

TABLE 3-3 (continued)

METEOROLOGICAL INPUTS FOR THE DEER CREEK LAKE TRIALS

Trial Number	Sampling Period LST*	Mean Wind Direction (degrees)	Wind Speed @ 2 meters $\bar{u}_R$ (m sec^{-1})	Wind Profile Exponent p	Standard Deviation of the Vertical Wind Direction σ'_E (radians)	Standard Diviation of the Horizontal Wind Direction σ'_A (radians)
14	1205-1225	260	3.4	0.27	0.0506	0.1710
15	1527-1547	236	4.0	0.23	0.0419	0.1431
16	1121-1141	214	3.8	0.14	0.0541	0.1885
17	1431-1451	228	5.5	0.16	0.0611	0.2129
18	1636-1656	224	4.6	0.12	0.0314	0.1100
19	2151-2211	209	1.1	0.31	0.0489	0.1676
20	1139-1159	288	3.0	0.09	0.0820	0.2827
21	1105-1125	196	2.4	0.12	0.0890	0.3089
22	1135-1155	221	3.6	0.18	0.0471	0.1623
23	1238-1258	230	3.9	0.12	0.0506	0.1728
24	1520-1540	231	3.9	0.11	0.0541	0.1885
25	1735-1755	211	2.9	0.15	0.0279	0.0942

*LST - Local Standard Time

TABLE 3-4

SOURCE STRENGTHS FOR THE 1974 FT. HUACHUCA TRIALS

Trial Number	Source Emission Rate (Q)			
	Biological Trials (organisms/minute)			Dye Trials (nanograms/minute)
	Total Aerobic	Coliforms, Endo agar	Coliforms, Endo broth	
1	1.87×10^{11}	1.46×10^{11}	1.08×10^{9}	
2	2.49×10^{11}	3.25×10^{10}	4.29×10^{8}	
7	8.45×10^{10}	5.29×10^{10}	4.04×10^{9}	
8	2.04×10^{10}	2.29×10^{9}	2.08×10^{5}	
9	7.29×10^{10}	2.08×10^{9}	1.58×10^{9}	
10	7.91×10^{10}	1.04×10^{10}	2.29×10^{10}	
11	1.58×10^{11}	1.37×10^{11}	2.04×10^{8}	
12	1.62×10^{11}	1.04×10^{11}	1.46×10^{8}	
16				2.58×10^{9}

TABLE 3-5

SOURCE STRENGTHS FOR THE 1975 FT. HUACHUCA TRIALS

Trial Number	Source Emission Rate (Q)				
	Biological Trials (organisms/minute)				Dye Trials (nanograms/minute)
	Standard Plate Count	Coliforms, Endo agar	Coliforms, Endo broth	Coliphage F2	
1	1.67×10^{11}	2.83×10^{9}	3.75×10^{7}		
2	1.64×10^{11}			2.04×10^{11}	
3	1.12×10^{10}			1.83×10^{11}	
5	3.66×10^{7}				
7	1.50×10^{11}			4.12×10^{11}	
8	1.71×10^{11}			5.41×10^{11}	
10	7.08×10^{10}	1.37×10^{10}			
11	1.67×10^{11}			6.74×10^{10}	
12	6.66×10^{10}	2.00×10^{10}			
13	2.08×10^{7}			2.19×10^{10}	
16					3.91×10^{8}
17					1.64×10^{9}

TABLE 3-6

SOURCE PARAMETERS FOR THE FT. HUACHUCA TRIALS

Parameter	Value (meters)
σ_{yR}	15.81
σ_{zR}	1.91
x_{Ry}	-0-
x_{Rz}	-0-
H	0.6

speed power-law coefficient p for each trial period was based on a scheme relating p with the measured wind speed at 2 meters and the net radiation index developed for White Sands Missile Range New Mexico by Dumbauld and Bjorklund (1977)[9]. Values of p as a function of wind speed and net radiation index are given in Table 3-7. The net radiation index is specified by the solar altitude angle for the time of day at Ft. Huachuca and the cloud cover observed during the trial. Values of the net radiation index for use when cloud cover is less than or equal to 0.4 are given in Table 3-8. When the cloud cover is greater than 0.4, the indices in Table 3-8 are adjusted as follows:

- If the cloud ceiling height is less than 2 kilometers during daytime, the index is reduced by 2
- If the cloud ceiling is equal to or greater than 2 kilometers during daytime, the index is reduced by 1
- The minimum adjusted index for daytime is 1
- For nighttime, the net radiation index is -1

Values of the mean wind direction, mean wind speed, p, σ'_E and σ'_A for the 1974 and 1975 Ft. Huachuca trials are respectively given in Tables 3-9 and 3-10. The remaining meteorological model input parameter were identical to those used for the Deer Creek Lake trials.

TABLE 3-7

WIND POWER-LAW EXPONENT p AS A FUNCTION OF NET RADIATION INDEX AND WIND SPEED

Wind Speed @ 2 meters (m/sec)	Net Radiation Index					
	4	3	2	1	0	-1
$\bar{u} \le 1$	.20	.20	.20	.20	.20	.20
$1 \le \bar{u} < 3$	.17	.17	.20	.20	.20	.20
$3 \le \bar{u} < 5$	.15	.15	.17	.17	.20	.20
$5 \le \bar{u} < 7$	.10	.10	.15	.15	.15	.15
$7 \le \bar{u}$	.05	.10	.10	.10	.15	.15

TABLE 3-8

NET RADIATION INDICES FOR CLOUD COVER $\le$ 0.4

Solar Altitude η In Degrees	Net Radiation Index
$\eta < 60$	4
$35 < \eta \le 60$	3
$15 < \eta \le 35$	2
$0 < \eta \le 15$	1
Nighttime	-1

TABLE 3-9

METEOROLOGICAL INPUTS FOR THE 1974 FT. HUACHUCA TRIALS

Trial Number	Sampling Period LST*	Mean Wind Direction (degrees)	Wind Speed @ 2 meters $\bar{u}_R$ (m sec^{-1})	Wind Profile Exponent p	Standard Deviation of the Vertical Wind Direction σ'_E (radians)	Standard Diviation of the Horizontal Wind Direction σ'_A (radians)
1	1310-1350	131	4.1	0.15	0.0455	0.1798
2	1136-1146	093	5.4	0.15	0.0702	0.2100
	1146-1156	097	4.7	0.15	0.1446	0.4328
	1156-1206	127	4.5	0.15	0.0440	0.1316
	1206-1216	123	4.9	0.15	0.0362	0.1082
7	1458-1528	120	3.8	0.15	0.0480	0.1897
8	0946-1006	106	6.4	0.10	0.0505	0.1737
9	1143-1213	097	6.5	0.10	0.0495	0.1847
10	1345-1355	088	6.7	0.10	0.0911	0.2726
	1355-1405	104	6.7	0.10	0.0618	0.1848
	1405-1415	105	5.2	0.10	0.0772	0.2309
	1415-1425	98	5.6	0.10	0.1089	0.3252

*LST - Local Standard Time

TABLE 3-9 (continued)

METEOROLOGICAL INPUTS FOR THE 1974 FT. HUACHUCA TRIALS

Trial Number	Sampling Period LST*	Mean Wind Direction (degrees)	Wind Speed @ 2 meters $\bar{u}_R$ (m sec^{-1})	Wind Profile Exponent p	Standard Deviation of the Vertical Wind Direction σ'_E (radians)	Standard Diviation of the Horizontal Wind Direction σ'_A (radians)
10 (cont.)	1425 1435	100	5.7	0.10	0.0479	0.1435
11	1135-1145	058	1.8	0.20	0.2374	0.7104
	1145-1155	075	1.9	0.20	0.1884	0.5637
	1155-1205	031	2.5	0.20	0.1995	0.5969
	1205-1215	060	2.3	0.20	0.1540	0.4608
12	1400-1410	006	2.7	0.17	0.2473	0.7400
	1410-1420	034	2.4	0.17	0.1382	0.4136
	1420-1430	023	1.9	0.20	0.0601	0.1798
	1430-1440	059	1.7	0.20	0.1277	0.3822
16	1015-1055	127	4.4	0.15	0.0542	0.2786

*LST - Local Standard Time

TABLE 3-10

METEOROLOGICAL INPUTS FOR THE 1975 FT. HUACHUCA TRIALS

Trial Number	Sampling Period LST*	Mean Wind Direction (degrees)	Wind Speed @ 2 meters $\bar{u}_R$ (m sec^{-1})	Wind Profile Exponent p	Standard Deviation of the Vertical Wind Direction σ'_E (radians)	Standard Deviation of the Horizontal Wind Direction σ'_A (radians)
1	1405-1415	289	4.0	0.15	0.1415	0.4235
	1415-1425	259	4.1	0.15	0.0569	0.1703
	1425-1435	242	3.8	0.15	0.0552	0.1653
	1435-1445	236	4.1	0.15	0.0553	0.1655
2	1638-1708	262	3.7	0.17	0.0421	0.1569
3	1445-1515	242	3.0	0.17	0.0594	0.2214
5	1110-1120	132	2.3	0.17	0.1603	0.4798
	1120-1130	109	2.0	0.17	0.2138	0.6397
	1130-1140	081	2.5	0.17	0.1402	0.4196
	1140-1150	068	1.9	0.17	0.1348	0.4035
7	1828-1858	246	1.9	0.20	0.0224	0.1325
8	2032-2042	360	2.2	0.20	0.0506	0.0902
	2042-2047	029	1.8	0.20	0.0506	0.5009

*LST - Local Standard Time

TABLE 3-10 (continued)

METEOROLOGICAL INPUTS FOR THE 1975 FT. HUACHUCA TRIALS

Trial Number	Sampling Period LST*	Mean Wind Direction (degrees)	Wind Speed @ 2 meters $\bar{u}_R$ (m sec^{-1})	Wind Profile Exponent p	Standard Deviation of the Vertical Wind Direction σ'_E (radians)	Standard Deviation of the Horizontal Wind Direction σ'_A (radians)
8 (cont.)	2047-2052	048	1.8	0.20	0.0506	0.8447
	2052-2102	129	2.2	0.20	0.0506	0.4737
10	1147-1217	128	3.1	0.15	0.1466	0.5465
11	1402-1417	122	5.0	0.15	0.0541	0.1755
12	1544-1614	143	3.5	0.15	0.0685	0.2553
13	1105-1115	121	4.6	0.15	0.0372	0.1114
	1115-1122	122	4.9	0.15	0.1078	0.3004
	1122-1132	215	4.5	0.15	0.0927	0.2773
16	1109-1127	122	2.2	0.17	0.1838	0.6187
17	1638-1658	269	2.6	0.20	0.0360	0.1962

*LST - Local Standard Time

SECTION 4

RESULTS OF THE CONCENTRATION CALCULATIONS

The Volume Source Diffusion Model described in Section 2 and the model inputs given in Section 3 were used to calculate aerosol concentrations at the sampler locations and concentration isopleths for the Deer Creek Lake study and the 1974-1975 Ft. Huachuca trials conducted by USAMBRDL. A major objective of this study was to estimate the aerosolization efficiency of the spray systems for bacteria or dye contained in the wastewater supplied to the spray irrigation systems. Aerosolization efficiency is defined by the ratio of the concentration measured at a sampling station to the concentration calculated by the predictive model at the station, assuming no losses of material occur during the aerosolization process or as the result of gravitational settling or other removal processes. Detailed results of the calculations are presented in Appendices A through F. Measured and calculated concentrations and the calculated aerosolization efficiencies for the Deer Creek Lake trials, the 1974 Ft. Huachuca trials and the 1975 Ft. Huachuca trials analyzed in this study are respectively presented in Appendices A, B and C. Corresponding concentration isopleths for the three trial series are shown in Appendices D, E and F. The concentration isopleths for the Deer Creek Lake trials contained in Appendix D were calculated using the source strengths in Table 3-1. The isopleths are labelled in units of viable counts per cubic meter for the biological trials and in nanograms per cubic meter for the dye trials and can thus be compared directly with the model concentrations presented in Table A-1 of Appendix A. The concentration isopleths for the Ft. Huachuca trials in Appendices E and F were calculated using a unit emission rate of 1 viable particle or 1 nanogram of dye per second. Therefore, absolute units of concentration can be obtained by multiplying the indicated isopleth value by the actual emission rates presented in Table 3-4 for the 1974 Ft. Huachuca trials and Table 3-5 for the 1975 Ft. Huachuca trials.

The results of the aerosolization efficiency calculations for the Deer Creek Lake trials are summarized in Table 4-1, which shows the geometric mean aerosolization efficiency as a function of distance from the center of the spray irrigation field and 95 percent confidence bands about the geometric means calculated using the normal statistic. The geometric mean aerosolization efficiencies shown in the table for the distance interval 87 to 97 meters are thus the geometric mean efficiency for all samples located 87 to 97 meters from the center of the spray irrigation field. The mean efficiencies and confidence bands shown for "all distances" were obtained by grouping the aerosolization efficiencies for all samples. If no removal processes were active, the aerosolization efficiencies should tend to remain constant with increasing distance from the spray irrigation field and should decrease with distance if removal processes (decay, air-shock, gravitational deposition, etc.) are

TABLE 4-1

GEOMETRIC MEAN AEROSOLIZATION EFFICIENCIES
FOR THE DEER CREEK TRIALS

Distances (Meters)	Biological Trials		Dye Trials	
	Mean	95% Confidence Band	Mean	95% Confidence Band
87-97	2.70×10^{-3}	2.14×10^{-3}-3.39×10^{-3}	3.13×10^{-3}	1.84×10^{-3}-5.34×10^{-3}
107-117	2.74×10^{-3}	2.15×10^{-3}-3.48×10^{-3}	5.66×10^{-3}	2.76×10^{-3}-1.16×10^{-2}
244-278	1.26×10^{-3}	5.10×10^{-4}-3.13×10^{-3}	1	1
All Distances	2.53×10^{-3}	2.13×10^{-3}-2.99×10^{-3}	5.61×10^{-3}	3.46×10^{-3}-9.10×10^{-3}

1 Insufficient sample size.

occurring. Inspection of Table 4-1 shows a slight tendency for the mean aerosolization efficiencies to decrease at the longer downwind distances for the biological trials. The geometric mean aerosolization efficiencies for the dye trials at Deer Creek Lake show a tendency to increase with distance from the spray irrigation field, although the increase is not significant. An increase in aerosolization efficiency can occur because the measured concentrations decrease with distance at a greater rate than predicted by the dispersion model or because the measured concentrations may be near background or near the limit of instrument detection so that division by the corresponding model concentration results in an artificial increase of aerosolization efficiency.

As shown in Table 4-1, the mean aerosolization efficiency for the dye trials is about a factor of 2 greater than the mean aerosolization efficiency for the biological trials. Under normal circumstances, the aerosolization efficiency for dye should be equal to or greater than the efficiency for biological material, depending on the loss of viable biological material due to air shock and other decay processes. The fractional biological aerosol depletion due to air shock and biological decay can thus be estimated from the expression

$$VL = 1 - \frac{E_B}{E_D} \tag{4-1}$$

where

VL = Fractional viability loss

E_B = Aerosolization efficiency for the biological material

E_D = Aerosolization efficiency for the dye

If the mean efficiencies for the biological and dye trials in Table 4-1 are used in Equation (4-1), the viability loss for the Deer Creek trials is about 55 percent. If the aerosolization efficiencies for biological Trial 19, which was conducted during the nighttime when decay might be less, are not considered in forming the mean aerosolization efficiency for biological trials, the viability loss is increased to 66 percent.

Summaries of the results of the calculations for the 1974 and 1975 Ft. Huachuca trials are respectively given in Tables 4-2 and 4-3. Results of the standard plate count aerosolization efficiency for Trials 5 and 13 have not been included in Table 4-3 for the 1975 Ft. Huachuca trials because the wastewater was chlorinated for these trials and a significant aerosol increase above background was not demontrated. The aerosolization efficiencies for Coliphage F2 for Trial 13 have been included because chlorination does not appear to reduce significantly the concentration of Coliphage F2 in the wastewater.

TABLE 4-2

GEOMETRIC MEAN AEROSOLIZATION EFFICIENCIES FOR THE 1974 FT. HUACHUCA TRIALS

a) Biological Trials

Distance (meters)	Standard Plate Count		Coliforms, Endo agar		Coliforms, Endo broth	
	Mean	95% Confidence Bands	Mean	95% Confidence Bands	Mean	95% Confidence Bands
46-49	7.53×10^{-4}	5.16×10^{-4}-1.10×10^{-3}	9.47×10^{-4}	2.03×10^{-4}-4.42×10^{-3}	1	
61-69	9.53×10^{-4}	3.37×10^{-4}-2.70×10^{-3}	3.37×10^{-4}	5.89×10^{-5}-1.93×10^{-3}	1	
91-107	4.53×10^{-4}	2.66×10^{-4}-7.71×10^{-4}	1		1	
152-198	4.14×10^{-4}	1.60×10^{-4}-1.08×10^{-3}	1		1	
All	5.77×10^{-4}	4.11×10^{-4}-8.10×10^{-4}	5.95×10^{-4}	2.47×10^{-4}-1.43×10^{-3}	1.78×10^{-3}	4.89×10^{-5}-6.50×10^{-2}

b) Dye Trials

Distance (meters)	Mean	95% Confidence Bands
46-49	1	
61-69	1.38×10^{-2}	5.40×10^{-3}-3.55×10^{-2}
91-107	1	
152-198	1	
All	1.31×10^{-2}	6.78×10^{-3}-2.54×10^{-2}

1 Insufficient Sample Size

TABLE 4-3

GEOMETRIC MEAN AEROSOLIZATION EFFICIENCIES FOR THE 1975 FT. HUACHUCA TRIALS

a) Biological Trials

Distance (1) (meters)	Standard Plate Count		Coliphage F2		Coliforms, Endo agar	
	Mean	95% Confidence Bands	Mean	95% Confidence Bands	Mean	95% Confidence Bands
46-52	1.34×10^{-3}	5.42×10^{-4}-3.32×10^{-3}	4.61×10^{-4}	2.52×10^{-4}-8.42×10^{-4}	(2)	
61-76	5.03×10^{-3}	3.12×10^{-3}-8.10×10^{-3}	4.71×10^{-4}	2.12×10^{-4}-1.05×10^{-3}	(2)	
All	2.18×10^{-3}	1.22×10^{-3}-3.91×10^{-3}	4.44×10^{-4}	2.82×10^{-4}-6.98×10^{-4}	4.66×10^{-4}	1.14×10^{-4}-1.90×10^{-3}

b) Dye Trials

Distance (meters)	Mean	95% Confidence Bands
46-52	7.06×10^{-2}	8.72×10^{-3}-5.71×10^{-1}
61-76	(2)	
All	4.16×10^{-2}	4.98×10^{-3}-3.47×10^{-1}

(1) Sampling was accomplished at distances beyond 76 meters, but sample size was low.

(2) Insufficient sample size.

Comparison of the results for the Ft. Huachuca trials in Tables 4-2 and 4-3 with those in Table 4-1 for the Deer Creek Lake trials indicates that the aerosolization efficiencies for the standard plate count in the 1974 Ft. Huachuca trials were significantly less than for either the 1975 Ft. Huachuca or Deer Creek Lake trials. We are unable to explain this difference in terms of the model calculations or the meteorological input parameters used in the dispersion model. Also, the 95 percent confidence bands about the mean aerosolization efficiencies appear broader for the Ft. Huachuca trials than for the Deer Creek trials. The greater variability in the aerosolization efficiency estimates for the Ft. Huachuca trials may be largely due to the differences in the experimental design between the Ft. Huachuca and Deer Creek Lake trials. Because sampling was accomplished downwind from a large area source in the Deer Creek Lake trials, the sampler position with respect to the downwind trajectory of dispersing material is not nearly as sensitive to the estimated cloud trajectory as is the case when sampling downwind from a single volume source.

All the 1974 Ft. Huachuca trials used in this study were conducted during daytime. The viability loss calculated using Equation (4-1) and the mean aerosolization efficiencies in Table 4-2 for standard plate count and the coliform levels estimated by the spread plate method on Endo agar and by the membrane filter method using m-Endo broth are respectively 96, 95 and 86 percent. It should be noted that the mean aerosolization efficiency for dye in Table 4-2 is based on the results from a single trial (Trial 16).

The viability loss calculated for the 1975 Ft. Huachuca trials using the mean aerosolization efficiencies shown in Table 4-3 for standard plate count, Coliphage F2 and Coliforms estimated by the spread plate method on Endo agar are respectively 95, 99 and 99 percent. The mean aerosolization efficiency for dye trials in this case are based on the results of two trials (Trials 16 and 17) conducted during daytime. Two of the 1975 Ft. Huachuca biological trials used in this study, Trials 7 and 8, were conducted after sunset. If the aerosolization efficiencies for these trials are not considered in forming the mean aerosolization efficiency for the standard plate count and Coliphage F2 (Coliform levels were not sampled in Trials 7 and 8), the viability loss for the standard plate count and Coliphage F2 remains virtually unchanged.

Finally, if we include the calculated aerosolization efficiencies for the 1974 Ft. Huachuca trials, Table 4-4 shows the geometric mean aerosolization efficiencies for the biological materials and the dye for all the trials analyzed in this study. The viability loss of the biological materials estimated from Equation (4-1) is also shown in Table 4-4.

TABLE 4-4

SUMMARY AEROSOLIZATION EFFICIENCIES AND VIABILITY LOSSES FOR ALL TRIALS ANALYZED

Material	Geometric Mean Aerosolization Efficiency	95% Confidence Bands	Viability Loss 1/ (Percent)
Standard Plate	1.98×10^{-3}	1.69×10^{-3}–2.33×10^{-3}	76
Coliforms, Endo agar	5.64×10^{-4}	2.76×10^{-4}–1.15×10^{-3}	93
Coliforms, Endo broth	2.26×10^{-3}	9.78×10^{-5}–5.22×10^{-2}	72
Coliphage F2	4.44×10^{-4}	2.82×10^{-4}–6.98×10^{-4}	95
Dye	8.10×10^{-3}	5.08×10^{-3}–1.29×10^{-2}	0

1/ Calculated from Equation (4-1).

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APPENDIX A

TABLE OF OBSERVED CONCENTRATIONS, PREDICTIVE MODEL CONCENTRATIONS AND AEROSOLIZATION EFFICIENCIES FOR THE 1976 DEER CREEK WASTEWATER TRIALS

TABLE A-1

OBSERVED CONCENTRATIONS, MODEL CONCENTRATIONS AND AEROSOLIZATION EFFICIENCIES FOR THE 1976 DEER CREEK WASTEWATER TRIALS

RUN NUMBER 1

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	552	4.85×10^{5}	1.14×10^{-3}
2	713	4.87×10^{5}	1.46×10^{-3}
3	-	4.90×10^{5}	-
4	243	4.91×10^{5}	4.95×10^{-4}
5	416	4.91×10^{5}	8.47×10^{-4}
6	653	3.98×10^{5}	1.67×10^{-3}
7	320	4.00×10^{5}	8.00×10^{-4}
8	375	4.02×10^{5}	9.33×10^{-4}
9	356	4.03×10^{5}	8.83×10^{-4}
10	366	4.05×10^{5}	9.04×10^{-4}
11	73	9.92×10^{4}	7.36×10^{-4}
12	99	1.04×10^{5}	9.52×10^{-4}
13	18	1.08×10^{5}	1.67×10^{04}

RUN NUMBER 2

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	475	1.14×10^{5}	4.16×10^{-3}
2	418	1.15×10^{5}	3.64×10^{-3}
3	-	1.16×10^{5}	-
4	157	1.16×10^{5}	1.35×10^{-3}
5	387	1.16×10^{5}	3.33×10^{-3}
6	715	8.98×10^{4}	7.96×10^{-3}
7	447	9.06×10^{4}	4.93×10^{-3}
8	330	9.12×10^{4}	3.62×10^{-3}
9	468	9.18×10^{4}	5.10×10^{-3}
10	362	9.23×10^{4}	3.92×10^{-3}
11	84	1.83×10^{4}	4.59×10^{-3}
12	-	1.91×10^{4}	-
13	212	1.99×10^{4}	1.07×10^{-2}

TABLE A-1 (Continued)

RUN NUMBER 3

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	526	2.24×10^5	2.35×10^{-3}
2	310	2.24×10^5	1.38×10^{-3}
3	319	2.24×10^5	1.42×10^{-3}
4	190	2.24×10^5	8.48×10^{-4}
5	586	2.24×10^5	2.62×10^{-3}
6	717	1.78×10^5	4.04×10^{-3}
7	739	1.78×10^5	4.15×10^{-3}
8	-	1.78×10^5	-
9	266	1.78×10^5	1.49×10^{-3}
10	346	1.78×10^5	1.94×10^{-3}
11	40	5.28×10^4	7.58×10^{-4}
12	-	5.33×10^4	-
13	52	5.38×10^4	9.67×10^{-4}

RUN NUMBER 4

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	267	1.11×10^5	2.41×10^{-3}
2	408	1.09×10^5	3.76×10^{-3}
3	155	1.06×10^5	1.46×10^{-3}
4	253	1.03×10^5	2.45×10^{-3}
5	214	1.00×10^5	2.14×10^{-3}
6	184	6.72×10^4	2.74×10^{-3}
7	58	6.48×10^4	8.94×10^{-4}
8	-	6.24×10^4	-
9	143	5.98×10^4	2.39×10^{-3}
10	55	5.71×10^4	9.64×10^{-4}
11	12	2.88×10^3	4.17×10^{-3}
12	-	2.65×10^3	-
13	0	2.42×10^3	0

TABLE A-1

RUN NUMBER 6

Sampler Number	Concentration (nanograms/m^3)		Aerosolization Efficiency
	Observed	Model	
1	-	1.10×10^4	-
2	0	1.14×10^4	0
3	168	1.17×10^4	1.43×10^{-2}
4	-	1.21×10^4	-
5	112	1.25×10^4	8.98×10^{-3}
6	-	4.88×10^3	-
7	-	5.17×10^3	-
8	191	5.46×10^3	3.50×10^{-2}
9	700	5.75×10^3	1.22×10^{-1}
10	84	6.03×10^3	1.39×10^{-2}
11	154	1.69×10^2	9.10×10^{-1}
12	-	1.84×10^2	-
13	21	2.00×10^2	1.05×10^{-1}

RUN NUMBER 7

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	1582	1.65×10^5	9.58×10^{-3}
2	1303	1.66×10^5	7.84×10^{-3}
3	-	1.67×10^5	-
4	1313	1.68×10^5	7.82×10^{-3}
5	712	1.68×10^5	4.23×10^{-3}
6	1248	1.31×10^5	9.50×10^{-3}
7	1209	1.33×10^5	9.09×10^{-3}
8	-	1.34×10^5	-
9	1290	1.35×10^5	9.52×10^{-3}
10	886	1.36×10^5	6.49×10^{-3}
11	329	1.04×10^5	3.17×10^{-3}
12	-	-	-
13	29	5.12×10^4	5.67×10^{-4}

TABLE A-1 (Continued)

RUN NUMBER 8

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	576	2.00×10^5	2.88×10^{-3}
2	507	2.00×10^5	2.54×10^{-3}
3	-	2.00×10^5	-
4	394	2.00×10^5	1.97×10^{-3}
5	73	1.99×10^5	3.66×10^{-4}
6	281	1.67×10^5	1.69×10^{-3}
7	530	1.67×10^5	3.18×10^{-3}
8	405	1.67×10^5	2.43×10^{-3}
9	461	1.66×10^5	2.77×10^{-3}
10	299	1.66×10^5	1.80×10^{-3}
11	111	1.22×10^5	9.11×10^{-4}
12	-	-	-
13	-	5.72×10^4	-

RUN NUMBER 9

Sampler Number	Concentration (nanograms/m^3)		Aerosolization Efficiency
	Observed	Model	
1	340	4.34×10^4	7.84×10^{-3}
2	89	4.44×10^4	2.01×10^{-3}
3	210	4.53×10^4	4.64×10^{-3}
4	72	4.61×10^4	1.56×10^{-3}
5	292	4.69×10^4	6.23×10^{-3}
6	280	3.04×10^4	9.21×10^{-3}
7	185	3.17×10^4	5.83×10^{-3}
8	194	3.30×10^4	5.88×10^{-3}
9	251	3.41×10^4	7.36×10^{-3}
10	215	3.51×10^4	6.12×10^{-3}
11	65	2.34×10^4	2.77×10^{-3}
12	-	-	-
13	88	7.99×10^3	1.10×10^{-2}

TABLE A-1 (Continued)

RUN NUMBER 10

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	883	2.81×10^4	3.15×10^{-2}
2	602	2.81×10^4	2.14×10^{-2}
3	309	2.81×10^4	1.10×10^{-2}
4	1217	2.81×10^4	4.34×10^{-2}
5	1217	2.80×10^4	4.34×10^{-2}
6	456	2.21×10^4	2.07×10^{-2}
7	765	2.21×10^4	3.46×10^{-2}
8	-	2.21×10^4	-
9	1429	2.22×10^4	6.45×10^{-2}
10	401	2.21×10^4	1.81×10^{-2}
11	155	1.89×10^4	8.19×10^{-3}
12	-	-	-
13	23	1.26×10^4	1.83×10^{-3}

RUN NUMBER 11

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	261	5.24×10^4	4.98×10^{-3}
2	266	5.24×10^4	5.08×10^{-3}
3	-	5.23×10^4	-
4	178	5.23×10^4	3.41×10^{-3}
5	261	5.21×10^4	5.01×10^{-3}
6	227	4.13×10^4	5.50×10^{-3}
7	243	4.13×10^4	5.88×10^{-3}
8	-	4.13×10^4	-
9	328	4.13×10^4	7.95×10^{-3}
10	127	4.12×10^4	3.08×10^{-3}
11	90	3.49×10^4	2.58×10^{-3}
12	-	-	-
13	74	2.29×10^4	3.23×10^{-3}

TABLE A-1 (Continued)

RUN NUMBER 12

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	200	5.20×10^4	3.84×10^{-3}
2	110	5.30×10^4	2.08×10^{-3}
3	-	5.38×10^4	-
4	149	5.46×10^4	2.73×10^{-3}
5	170	5.54×10^4	3.07×10^{-3}
6	266	3.49×10^4	7.61×10^{-3}
7	172	3.59×10^4	4.79×10^{-3}
8	-	3.69×10^4	-
9	262	3.77×10^4	6.94×10^{-3}
10	59	3.86×10^4	1.53×10^{-3}
11	93	3.54×10^4	2.63×10^{-3}
12	-	-	-
13	0	2.60×10^4	0

RUN NUMBER 13

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	132	4.12×10^4	3.20×10^{-3}
2	178	4.19×10^4	4.25×10^{-3}
3	-	4.25×10^4	-
4	136	4.31×10^4	3.16×10^{-3}
5	141	4.36×10^4	3.23×10^{-3}
6	76	2.95×10^4	2.58×10^{-3}
7	196	3.04×10^4	6.45×10^{-3}
8	-	3.12×10^4	-
9	251	3.19×10^4	7.86×10^{-3}
10	129	3.26×10^4	3.96×10^{-3}
11	42	2.64×10^4	1.59×10^{-3}
12	-	-	-
13	0	1.44×10^4	0

TABLE A-1 (Continued)

RUN NUMBER 14

Sampler Number	Concentration (counts/m^3) Observed	Model	Aerosolization Efficiency
1	239	1.87×10^5	1.28×10^{-3}
2	150	1.85×10^5	8.12×10^{-4}
3	-	1.82×10^5	-
4	150	1.79×10^5	8.40×10^{-4}
5	136	1.75×10^5	7.76×10^{-4}
6	71	1.39×10^5	5.10×10^{-4}
7	155	1.37×10^5	1.14×10^{-3}
8	-	1.34×10^5	-
9	129	1.30×10^5	9.99×10^{-4}
10	210	1.27×10^5	1.65×10^{-2}
11	58	9.19×10^4	6.31×10^{-4}
12	-	-	-
13	0	4.40×10^4	0

RUN NUMBER 15

Sampler Number	Concentration (counts/m^3) Observed	Model	Aerosolization Efficiency
1	46	2.15×10^5	2.14×10^{-4}
2	106	2.15×10^5	4.94×10^{-4}
3	-	2.15×10^5	-
4	128	2.15×10^5	5.96×10^{-4}
5	135	2.14×10^5	6.30×10^{-4}
6	69	1.78×10^5	3.88×10^{-4}
7	15	1.78×10^5	8.44×10^{-5}
8	-	1.78×10^5	-
9	71	1.78×10^5	4.00×10^{-4}
10	68	1.77×10^5	3.83×10^{-4}
11	4	5.93×10^4	6.75×10^{-5}
12	-	-	-
13	15	6.24×10^4	2.41×10^{-4}

TABLE A-1 (Continued)

RUN NUMBER 16

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	524	1.03×10^{5}	5.10×10^{-3}
2	810	1.03×10^{5}	7.83×10^{-3}
3	1144	1.04×10^{5}	1.10×10^{-2}
4	769	1.05×10^{5}	7.35×10^{-3}
5	1185	1.05×10^{5}	1.13×10^{-2}
6	585	8.29×10^{4}	7.05×10^{-3}
7	651	8.36×10^{4}	7.78×10^{-3}
8	-	8.43×10^{4}	-
9	909	8.48×10^{4}	1.07×10^{-2}
10	912	8.53×10^{4}	1.07×10^{-2}
11	179	2.96×10^{4}	6.05×10^{-3}
12	-	2.98×10^{4}	-
13	158	3.01×10^{4}	5.26×10^{-3}

RUN NUMBER 17

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	567	6.16×10^{4}	9.21×10^{-3}
2	367	6.16×10^{4}	5.96×10^{-3}
3	-	6.16×10^{4}	-
4	1000	6.16×10^{4}	1.62×10^{-2}
5	320	6.15×10^{4}	5.20×10^{-3}
6	406	4.84×10^{4}	8.40×10^{-3}
7	776	4.86×10^{4}	1.60×10^{-2}
8	-	4.88×10^{4}	-
9	175	4.89×10^{4}	3.58×10^{-3}
10	230	4.90×10^{4}	4.69×10^{-3}
11	0	8.11×10^{3}	0
12	-	8.53×10^{3}	-
13	0	8.95×10^{3}	0

TABLE A-1 (Continued)

RUN NUMBER 18

Sampler Number	Concentration (nanograms/m^3) Observed	Concentration (nanograms/m^3) Model	Aerosolization Efficiency
1	98	4.39×10^{4}	2.23×10^{-3}
2	27	4.38×10^{4}	6.16×10^{-4}
3	276	4.39×10^{4}	6.29×10^{-3}
4	164	4.39×10^{4}	3.73×10^{-3}
5	27	4.40×10^{4}	6.14×10^{-4}
6	93	3.72×10^{4}	2.50×10^{-3}
7	164	3.73×10^{4}	4.40×10^{-3}
8	-	3.74×10^{4}	-
9	170	3.74×10^{4}	4.54×10^{-3}
10	81	3.75×10^{4}	2.16×10^{-3}
11	45	2.68×10^{3}	1.68×10^{-2}
12	-	3.11×10^{3}	-
13	39	3.59×10^{3}	1.09×10^{-2}

RUN NUMBER 19

Sampler Number	Concentration (counts/m^3) Observed	Concentration (counts/m^3) Model	Aerosolization Efficiency
1	369	1.35×10^{5}	2.74×10^{-3}
2	346	1.36×10^{5}	2.54×10^{-3}
3	-	1.37×10^{5}	-
4	472	1.39×10^{5}	3.40×10^{-3}
5	392	1.40×10^{5}	2.81×10^{-3}
6	166	1.05×10^{5}	1.57×10^{-3}
7	401	1.07×10^{5}	3.75×10^{-3}
8	-	1.08×10^{5}	-
9	405	1.09×10^{5}	3.71×10^{-3}
10	350	1.10×10^{5}	3.18×10^{-3}
11	173	3.13×10^{4}	3.53×10^{-3}
12	-	3.20×10^{4}	-
13	223	3.27×10^{4}	6.82×10^{-3}

TABLE A-1 (Continued)

RUN NUMBER 20

Sampler Number	(Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	258	1.43×10^5	1.80×10^{-3}
2	341	1.46×10^5	2.33×10^{-3}
3	-	1.49×10^5	-
4	507	1.52×10^5	3.34×10^{-3}
5	233	1.54×10^5	1.52×10^{-3}
6	525	1.13×10^5	4.64×10^{-3}
7	258	1.15×10^5	2.24×10^{-3}
8	-	1.17×10^5	-
9	495	1.18×10^5	4.18×10^{-3}
10	304	1.20×10^5	2.54×10^{-3}
11	0	3.70×10^4	0
12	-	3.68×10^4	-
13	0	3.68×10^4	0

RUN NUMBER 21

Sampler Number	(Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	485	1.46×10^5	3.32×10^{-3}
2	292	1.48×10^5	1.97×10^{-3}
3	-	1.50×10^5	-
4	273	1.52×10^5	1.79×10^{-3}
5	296	1.54×10^5	1.92×10^{-3}
6	147	1.02×10^5	1.44×10^{-3}
7	114	1.04×10^5	1.09×10^{-3}
8	-	1.06×10^5	-
9	110	1.08×10^5	1.02×10^{-3}
10	129	1.10×10^5	1.17×10^{-3}
11	0	1.93×10^4	0
12	-	1.99×10^4	-
13	54	2.05×10^4	2.63×10^{-3}

TABLE A-1 (Continued)

RUN NUMBER 22

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	1323	1.39×10^5	9.51×10^{-3}
2	1303	1.39×10^5	9.37×10^{-3}
3	-	1.39×10^5	-
4	991	1.39×10^5	7.12×10^{-3}
5	1109	1.39×10^5	7.97×10^{-3}
6	984	1.15×10^5	8.59×10^{-3}
7	1148	1.15×10^5	1.00×10^{-2}
8	874	1.15×10^5	7.62×10^{-3}
9	1019	1.15×10^5	8.89×10^{-3}
10	911	1.15×10^5	7.95×10^{-3}
11	137	4.26×10^4	3.22×10^{-3}
12	-	4.23×10^4	-
13	148	4.18×10^4	3.54×10^{-3}

RUN NUMBER 23

Sampler Number	Concentration (nanograms/m^3)		Aerosolization Efficiency
	Observed	Model	
1	24	2.87×10^4	8.37×10^{-4}
2	203	2.86×10^4	7.10×10^{-3}
3	162	2.85×10^4	5.68×10^{-3}
4	149	2.85×10^4	5.24×10^{-3}
5	24	2.84×10^4	8.47×10^{-4}
6	12	2.36×10^4	5.09×10^{-4}
7	0	2.35×10^4	0
8	181	2.34×10^4	7.74×10^{-3}
9	95	2.32×10^4	4.09×10^{-3}
10	18	2.31×10^4	7.80×10^{-4}
11	0	6.76×10^3	0
12	-	6.51×10^3	-
13	0	6.26×10^3	0

TABLE A-1 (Continued)

RUN NUMBER 24

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	460	3.93×10^5	1.17×10^{-3}
2	448	3.92×10^5	1.14×10^{-3}
3	364	3.91×10^5	9.31×10^{-4}
4	549	3.89×10^5	1.41×10^{-3}
5	374	3.87×10^5	9.66×10^{-4}
6	402	3.20×10^5	1.26×10^{-3}
7	222	3.19×10^5	6.96×10^{-4}
8	397	3.17×10^5	1.25×10^{-3}
9	116	3.15×10^5	3.69×10^{-4}
10	504	3.12×10^5	1.62×10^{-3}
11	103	1.14×10^5	9.03×10^{-4}
12	-	1.13×10^5	-
13	1	1.12×10^5	8.96×10^{-6}

RUN NUMBER 25

Sampler Number	Concentration (counts/m^3)		Aerosolization Efficiency
	Observed	Model	
1	170	3.50×10^5	4.86×10^{-4}
2	165	3.51×10^5	4.70×10^{-4}
3	241	3.51×10^5	6.86×10^{-4}
4	428	3.51×10^5	1.22×10^{-3}
5	688	3.51×10^5	1.96×10^{-3}
6	0	3.00×10^5	0
7	40	3.07×10^5	1.30×10^{-4}
8	72	3.02×10^5	2.39×10^{-4}
9	504	3.02×10^5	1.67×10^{-3}
10	343	3.03×10^5	1.13×10^{-3}
11	0	1.26×10^5	0
12	-	1.28×10^5	-
13	0	1.31×10^5	0

APPENDIX B

TABLE OF OBSERVED CONCENTRATIONS, PREDICTIVE MODEL CONCENTRATIONS AND AEROSOLIZATION EFFICIENCIES FOR THE 1974 FT. HUACHUCA TRIALS

TABLE B-1

OBSERVED CONCENTRATIONS, MODEL CONCENTRATIONS AND AEROSOLIZATION EFFICIENCIES FOR THE 1974 FORT HUACHUCA WASTEWATER TRIALS

Trial No.	Sampler	Distance (m)	Azimuth (deg)	Concentration (counts/m^3)								
				Total Aerobic			Coliforms, Endo agar			Coliforms, Endo broth		
				Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency
1	A	152	298	46	3.79×10^{5}	1.21×10^{-4}						
	B	152	310	79	5.34×10^{5}	1.48×10^{-4}						
	C	152	315	89	5.19×10^{5}	1.71×10^{-4}	8.8	4.04×10^{5}	2.18×10^{-5}	0.75	3.00×10^{3}	2.50×10^{-4}
	D	152	320	28	4.57×10^{5}	6.13×10^{-5}						
	E											
	F	61	315	333	1.59×10^{6}	2.10×10^{-4}						
	G	46	315	1210	2.04×10^{6}	5.92×10^{-4}	146	1.59×10^{6}	9.19×10^{-5}			
2	A	152	262	39	9.37×10^{4}	4.16×10^{-4}						
	B	152	274	55	1.23×10^{5}	4.45×10^{-4}						
	C	152	280	137	1.53×10^{5}	8.94×10^{-4}	47	2.00×10^{4}	2.35×10^{-3}	46	2.64×10^{2}	1.74×10^{-1}
	D	152	286	154	2.18×10^{5}	7.06×10^{-4}						
	E	152	298	147	4.27×10^{5}	3.44×10^{-4}						
	F	91	280	200	4.87×10^{5}	4.11×10^{-4}	45	6.35×10^{4}	7.08×10^{-4}			
	G	46	280	506	7.50×10^{5}	6.75×10^{-4}	140	9.78×10^{4}	5.17×10^{-3}			

TABLE B-1 (Continued)

Trial No.	Sampler	Distance (m)	Azimuth (deg)	Concentration (counts/m^3)								
				Total Aerobic			Coliforms, Endo agar			Coliforms, Endo broth		
				Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency
7	A	61	285				48.4	4.01×10^{5}	1.21×10^{-4}			
	B	61	300				86.1	4.63×10^{5}	1.86×10^{-4}			
	C	61	315	822	6.33×10^{5}	1.30×10^{-3}	86.1	3.96×10^{5}	2.17×10^{-4}	36	3.02×10^{4}	1.19×10^{-3}
	D	61	330				46.0	2.49×10^{5}	1.85×10^{-4}			
	E	61	345				9.5	1.12×10^{5}	8.45×10^{-5}			
	F	152	315	8	1.55×10^{5}	5.16×10^{-5}	17.7	9.71×10^{4}	1.82×10^{-4}			
	G	46	315	1084	8.62×10^{5}	1.26×10^{-3}						
8	A	61	261	0	7.09×10^{4}							
	B	61	273	36.7	9.92×10^{4}	3.70×10^{-4}						
	C	61	285	426	1.12×10^{5}	3.80×10^{-3}	278	1.26×10^{4}	2.21×10^{-2}	10	1.14	8.74
	D	61	297	424	1.03×10^{5}	4.13×10^{-3}						
	E	61	309	51	7.61×10^{4}	6.70×10^{-4}						
	F	152	285	191	3.76×10^{4}	5.08×10^{-3}	264	4.22×10^{3}	6.26×10^{-2}			
	C	46	285	164	1.44×10^{5}	1.14×10^{-3}	209	1.62×10^{4}	1.29×10^{-2}			

TABLE B-1 (continued)

Trial No.	Sampler	Distance (m)	Azimuth (deg)	Concentration (counts/m^3)								
				Total Aerobic			Coliforms, Endo agar			Coliforms, Endo broth		
				Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency
9	A	107	263	31	1.59×10^{5}	1.95×10^{-4}						
	B	107	275	34	2.09×10^{5}	1.63×10^{-4}						
	C	107	292	37	1.56×10^{5}	2.37×10^{-4}	7	4.47×10^{3}	1.57×10^{-3}	0.6	3.40×10^{3}	1.77×10^{-4}
	D	107	309	37	4.95×10^{4}	7.48×10^{-4}						
	E	107	321		1.14×10^{4}							
	F	152	292	57	8.62×10^{4}	6.61×10^{-4}		2.46×10^{3}				
	G	49	292	70	4.32×10^{5}	1.62×10^{-4}	12	1.23×10^{4}	9.72×10^{-4}			
10	A											
	B											
	C	198	292	197	2.43×10^{4}	8.09×10^{-3}		3.20×10^{3}		0.2	7.05×10^{3}	2.84×10^{-5}
	D											
	E											
	F	107	292	213	1.43×10^{5}	1.49×10^{-3}	11	1.89×10^{4}	5.83×10^{-4}			
	G	49	292	177	4.00×10^{5}	4.43×10^{-4}	34	5.26×10^{4}	6.46×10^{-4}			

TABLE B-1 (continued)

Trial No.	Sampler	Distance (m)	Azimuth (deg)	Concentration (counts/m^3)								
				Total Aerobic			Coliforms, Endo agar			Coliforms, Endo broth		
				Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency
11	A	91	248	183	$1.98x10^5$	$9.22x10^{-4}$						
	B	91	260	147	$1.91x10^5$	$7.68x10^{-4}$						
	C	91	270	100	$1.78x10^5$	$5.62x10^{-4}$	13	$1.54x10^5$	$8.42x10^{-5}$	.09	$2.29x10^2$	$3.92x10^{-4}$
	D	91	280	41	$1.55x10^5$	$2.64x10^{-4}$						
	E	91	292		$1.22x10^5$							
	F	137	270		$7.67x10^4$			$6.66x10^4$				
	G	46	270	685	$6.43x10^5$	$1.07x10^{-3}$	208	$5.58x10^5$	$3.73x10^{-4}$			
12	A	46	238	734	$1.18x10^6$	$6.24x10^{-4}$						
	B	46	254	839	$9.44x10^5$	$8.89x10^{-4}$						
	C	46	270	603	$6.80x10^5$	$8.87x10^{-4}$	208	$4.36x10^5$	$4.77x10^{-4}$	.07	$6.10x10^2$	$1.15x10^{-4}$
	D	46	286	491	$4.45x10^5$	$1.10x10^{-3}$						
	E	46	302	335	$2.39x10^4$	$1.40x10^{-3}$						
	F	114	270		$7.21x10^4$			$4.62x10^4$				
	G	69	270	160	$2.38x10^5$	$6.72x10^{-4}$	45	$1.53x10^5$	$2.95x10^{-4}$			

TABLE B-1 (continued)

Trial Number	Sampler	Distance (m)	Azimuth (deg)	Dye Concentration (nanograms/m^3)		Aerosolization Efficiency
				Observed	Model	
16	A	61	275		9.90×10^{3}	
	B	61	290	124	1.34×10^{4}	9.26×10^{-3}
	C	61	305	388	1.49×10^{4}	2.60×10^{-2}
	D	61	320	106	1.39×10^{4}	7.63×10^{-3}
	E	61	335	214	1.07×10^{4}	2.00×10^{-2}
	F	152	305	26	4.31×10^{3}	6.03×10^{-3}
	G	46	305	462	2.00×10^{4}	2.31×10^{-2}

APPENDIX C

TABLE OF OBSERVED CONCENTRATIONS, PREDICTIVE MODEL CONCENTRATIONS AND AEROSOLIZATION EFFICIENCIES FOR THE 1975 FT. HUACHUCA TRIALS

TABLE C-1

OBSERVED CONCENTRATIONS, MODEL CONCENTRATIONS AND AEROSOLIZATION EFFICIENCIES FOR THE 1975 FORT HUACHUCA WASTEWATER TRIALS

Trial No.	Sampler	Distance (m)	Azimuth (deg)	Concentration (counts/m^3)								
				Standard Plate Count			Coliforms, Endo agar			Coliforms, Endo broth		
				Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency
1	A	46	343	18	7.27×10^{4}	2.47×10^{-4}						
	B	46	3	168	2.41×10^{5}	6.96×10^{-4}						
	C	46	43	4380	1.09×10^{6}	4.01×10^{-3}	45	1.84×10^{4}	2.44×10^{-3}			
	D	46	95	603	9.80×10^{5}	6.15×10^{-4}	12	1.67×10^{4}	7.20×10^{-4}	3.3	2.20×10^{2}	1.50×10^{-2}
	E	46	125	54	4.22×10^{5}	1.28×10^{-4}	8	7.17×10^{3}	1.12×10^{-3}			
	F	46	175	14	8.46×10^{4}	1.65×10^{-4}						
	G	92	180	18	2.29×10^{3}	7.87×10^{-3}						

TABLE C-1 (continued)

Trial No.	Sampler	Distance (m)	Azimuth (deg)	Concentration (counts/m^3)					
				Standard Plate Count			Coliphage F2		
				Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency
2	A	46	3					1.55×10^5	
	B	46	48		1.16×10^6		959	1.43×10^6	6.69×10^{-4}
	C	76	83				2390	1.67×10^6	1.43×10^{-3}
	D	46	101	4210	1.74×10^6	2.42×10^{-3}	4860	2.16×10^6	2.25×10^{-3}
	E	52	128	49	5.07×10^5	9.67×10^{-5}	35	6.29×10^5	5.57×10^{-5}
	F	46	178				812		
	G								
3	A	76	33				63	6.75×10^5	9.33×10^{-5}
	B	76	68	124	7.58×10^4	1.64×10^{-3}	98	1.24×10^6	7.93×10^{-5}
	C	76	93				37	6.21×10^5	5.96×10^{-5}
	D	152	68	1	2.81×10^4	3.56×10^{-5}	10	4.58×10^5	2.18×10^{-5}
	E	46	68	150	1.33×10^5	1.13×10^{-3}	236	2.16×10^6	1.09×10^{-4}
	F								
	G								

TABLE C-1 (continued)

Trial No.	Sampler	Distance (m)	Azimuth (deg)	Concentration (counts/m^3)					
				Standard Plate Count			Coliphage F2		
				Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency
5	A	46	253	22	1.77×10^{2}	1.24×10^{-1}			
	B	46	273	27	1.98×10^{2}	1.36×10^{-1}			
	C	46	291	57	1.89×10^{2}	3.02×10^{-1}			
	D	46	321	21	1.48×10^{2}	1.42×10^{-1}			
	E	46	338	18	1.12×10^{2}	1.61×10^{-1}			
	F	76	291	28	7.71×10^{1}	3.63×10^{-1}			
	G								
7	A	46	58				3070	1.30×10^{7}	2.36×10^{-4}
	B	46	93	10500	3.08×10^{6}	3.40×10^{-3}	1310	8.48×10^{6}	1.54×10^{-4}
	C	46	123					2.06×10^{6}	
	D	152	93	264	1.71×10^{5}	1.54×10^{-3}		4.71×10^{5}	
	E	76	93	3930	1.31×10^{6}	3.01×10^{-3}	829	3.59×10^{6}	2.31×10^{-4}
	F								
	G								

TABLE C-1 (continued)

Trial No.	Sampler	Distance (m)	Azimuth (deg)	Concentration (counts/m^3)					
				Standard Plate Count			Coliphage F2		
				Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency
8	A	46	43				1810	9.28×10^5	1.95×10^{-3}
	B	46	53	4550	2.82×10^5	1.62×10^{-2}	1360	8.93×10^5	1.52×10^{-3}
	C	46	93	2290	4.97×10^5	4.61×10^{-3}	1360	1.58×10^6	8.63×10^{-4}
	D	46	113	9880	7.13×10^5	1.39×10^{-2}	1380	2.26×10^6	6.10×10^{-4}
	E	46	153				1880	3.93×10^6	4.78×10^{-4}
	F	46	193				1620	4.63×10^6	3.50×10^{-4}
	G	61	113	1870	4.10×10^5	4.56×10^{-3}	1570	1.30×10^6	1.21×10^{-3}

TABLE C-1 (continued)

Trial No.	Sampler	Distance (m)	Azimuth (deg)	Concentration (counts/m^3)								
				Total Aerobic			Coliforms, Endo agar			Coliforms, Endo broth		
				Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency
10	A	76	283	1690	1.15×10^{5}	1.47×10^{-2}						
	B	76	313	502	1.24×10^{5}	4.05×10^{-3}	2	2.41×10^{4}	6.31×10^{-5}			
	C	76	333	730	1.21×10^{5}	6.05×10^{-3}						
	D	101	313	183	7.68×10^{4}	2.38×10^{-3}	8	1.49×10^{4}	5.37×10^{-4}			
	E	46	313	221	2.69×10^{5}	8.21×10^{-4}	8	5.23×10^{4}	1.53×10^{-4}			
	F											
	G											

TABLE C-1 (continued)

Trial No.	Sampler	Distance (m)	Azimuth (deg)	Concentration (counts/m^3)					
				Standard Plate Count			Coliphage F2		
				Observed	Model	Aerosolization Efficiency	Observed	Model	Aerosolization Efficiency
11	A	76	283				134	2.42×10^5	5.54×10^{-4}
	B	76	313	4730	7.58×10^5	6.24×10^{-3}	268	3.07×10^5	8.73×10^{-4}
	C	76	333					1.34×10^5	
	D	101	313	1900	5.13×10^5	3.70×10^{-3}	343	2.08×10^5	1.65×10^{-3}
	E	46	313	1210	1.32×10^6	9.15×10^{-4}	296	5.35×10^5	5.53×10^{-4}
	F								
	G								

TABLE C-1 (continued)

Trial No.	Sampler	Dist-ance (m)	Azi-muth (deg)	Concentration (counts/m^3)					
				Standard Plate Count			Coliphage F2		
				Observed	Model	Aerosoli-zation Efficiency	Observed	Model	Aerosoli-zation Efficiency
12	A	76	283	323	$1.18x10^5$	$2.73x10^{-3}$			
	B	76	313	3800	$3.11x10^5$	$1.22x10^{-2}$	174	$9.32x10^4$	$1.87x10^{-3}$
	C	76	333	1910	$3.11x10^5$	$6.14x10^{-3}$			
	D	101	313	3210	$2.07x10^5$	$1.55x10^{-2}$	17	$6.20x10^4$	$2.74x10^{-4}$
	E	46	313	10200	$5.72x10^5$	$1.78x10^{-2}$	30	$1.72x10^5$	$1.75x10^{-4}$
	F								
	G								
13	A	76	283		$5.00x10^1$		21	$5.27x10^4$	$3.99x10^{-4}$
	B	76	313		$6.37x10^1$		111	$6.72x10^4$	$1.65x10^{-3}$
	C	76	333				28	$2.47x10^4$	$1.13x10^{-3}$
	D	101	313		$4.31x10^1$		50	$4.54x10^4$	$1.10x10^{-3}$
	E	46	313		$1.14x10^1$		128	$1.20x10^5$	$1.07x10^{-3}$
	F								
	G								

TABLE C-1 (Continued)

Trial Number	Sampler	Distance (m)	Azimuth (deg)	Dye Concentration (nanograms/m^3)		Aerosolization Efficiency
				Observed	Model	
16	A	46	180	110	0	
	B	46	225	460	1.10×10^3	4.20×10^{-1}
	C	46	270	130	1.60×10^3	8.12×10^{-2}
	D	46	315	190	1.53×10	1.25×10^{-1}
	E	46	0	680	1.64×10^3	4.14×10^{-1}
	F	46	45	310		
	G					
17	A	46	43	410	1.17×10^4	3.51×10^{-2}
	B	46	58		1.93×10^4	0
	C	46	93	58	2.91×10^4	2.00×10^{-3}
	D	46	123		1.76×10^4	0
	E	76	93	32	1.84×10^4	1.74×10^{-3}
	F					
	G					

APPENDIX D

CONCENTRATION ISOPLETH PATTERNS FOR THE 1976 DEER CREEK LAKE TRIALS

Computer plots of concentration isopleths in units of viable counts per cubic meter for 24 of the Deer Creek Lake trials are presented in this appendix. The abscissa of each plot is the crosswind distance along the upwind edge of the spray irrigation field with zero representing the center of the spray field. The ordinate of each plot is the distance from the upwind edge of the spray field with zero representing the center of the spray field. The small x's show sampler positions.

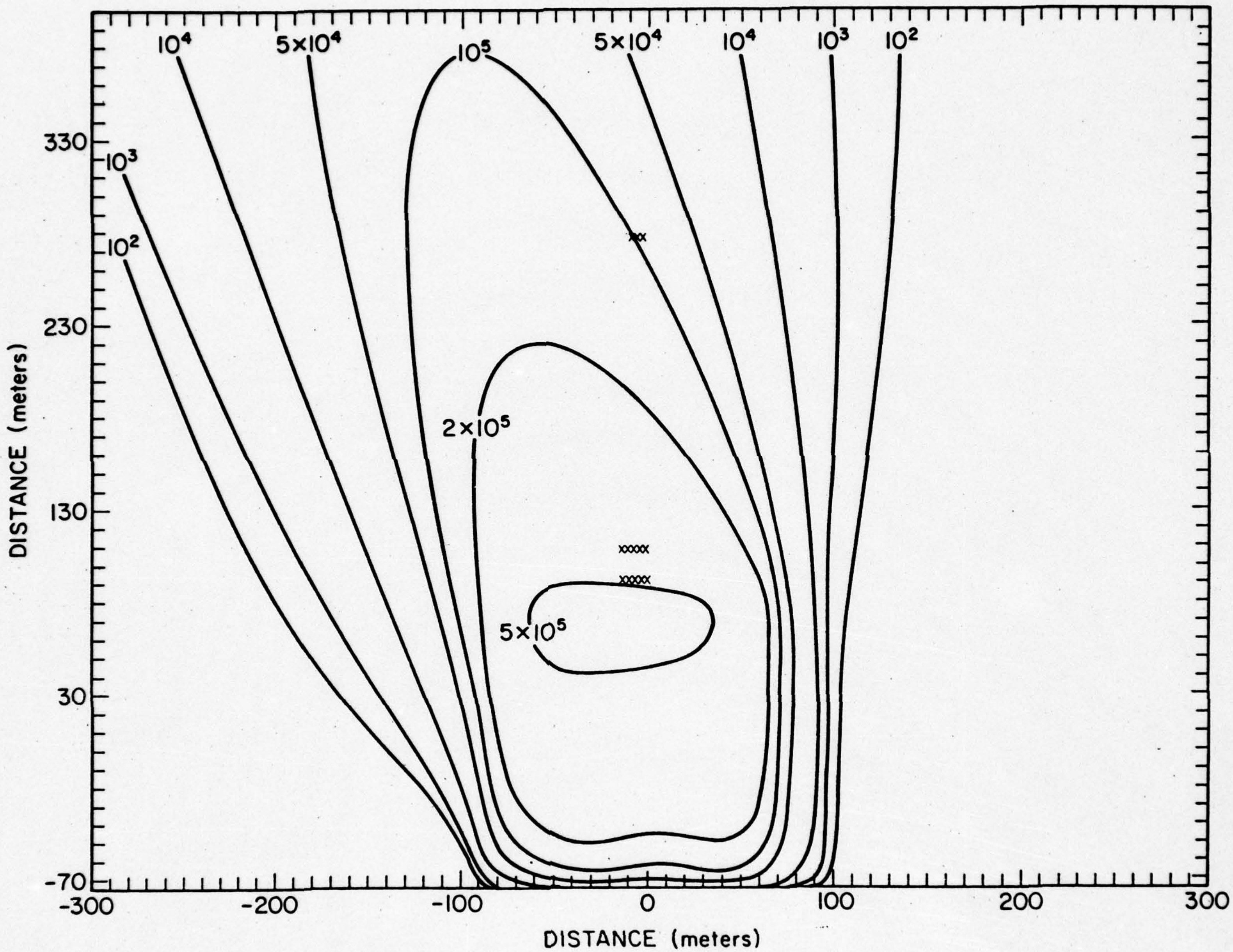

FIGURE 1-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 1 of the 1976 Deer Creek Lake Trials.

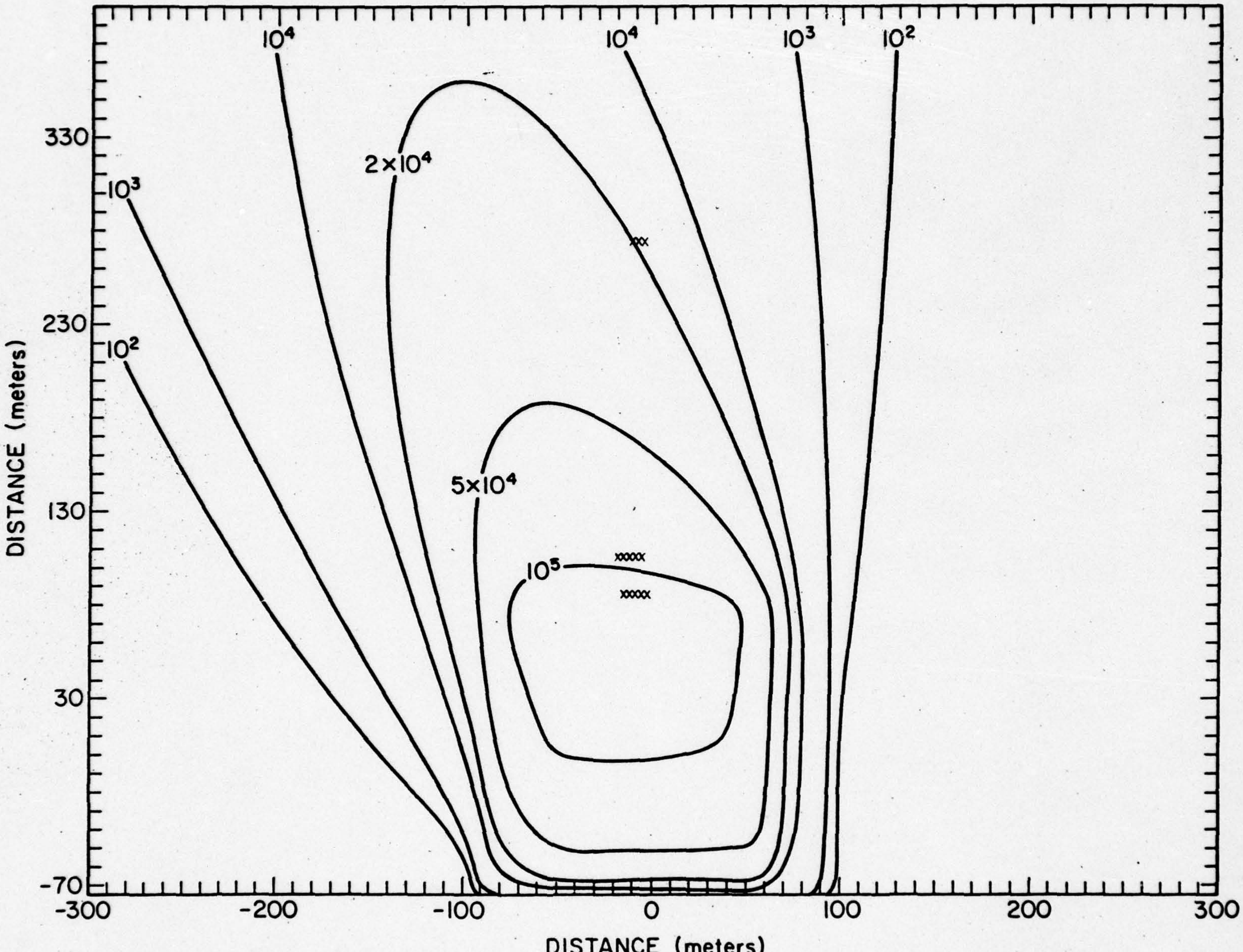

FIGURE 2-D. Isopleths of ground-level concentrations in units of viable counts per cubic meter for Run Number 2 of the 1976 Deer Creek Lake Trials.

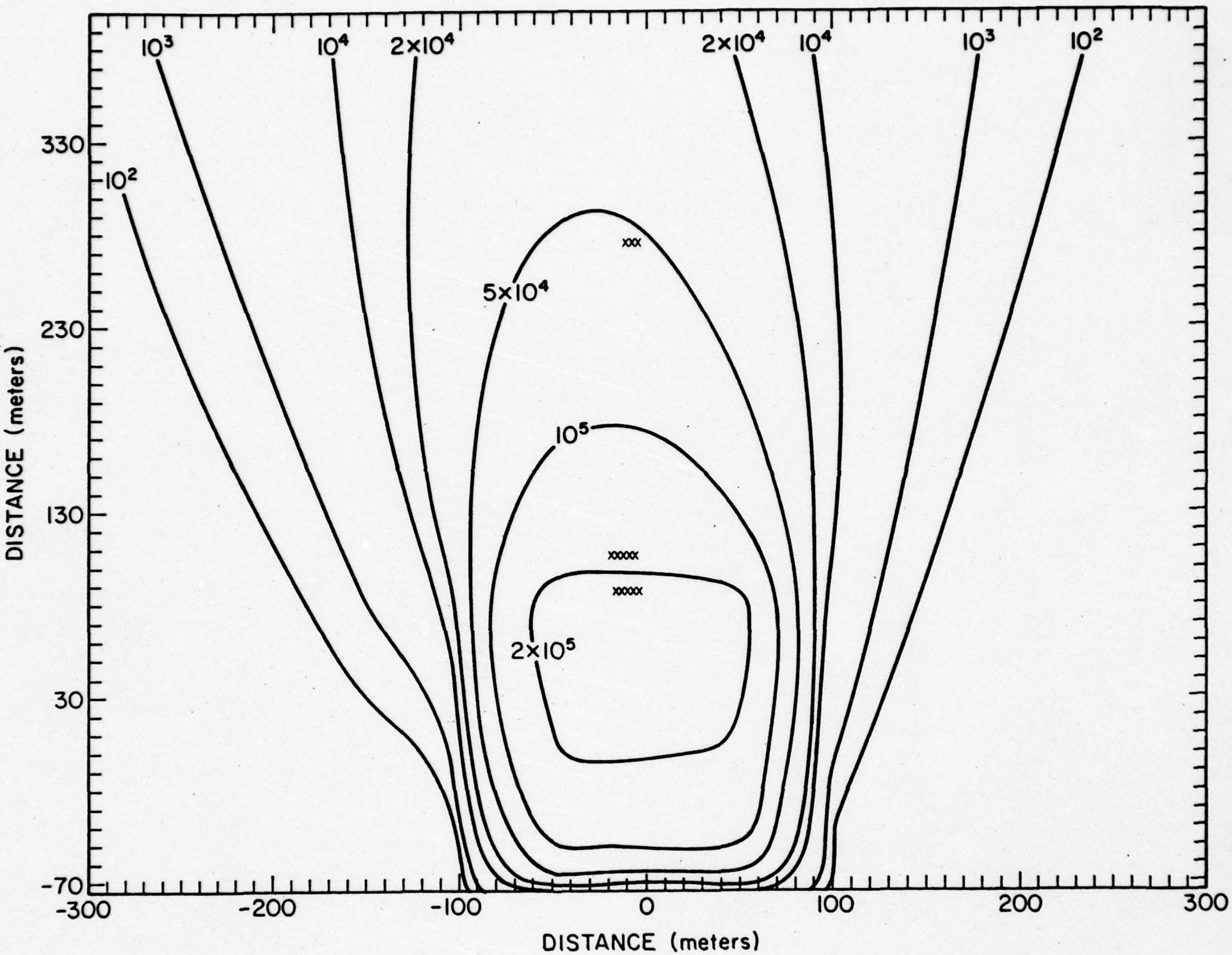

FIGURE 3-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 3 of the 1976 Deer Creek Lake Trials.

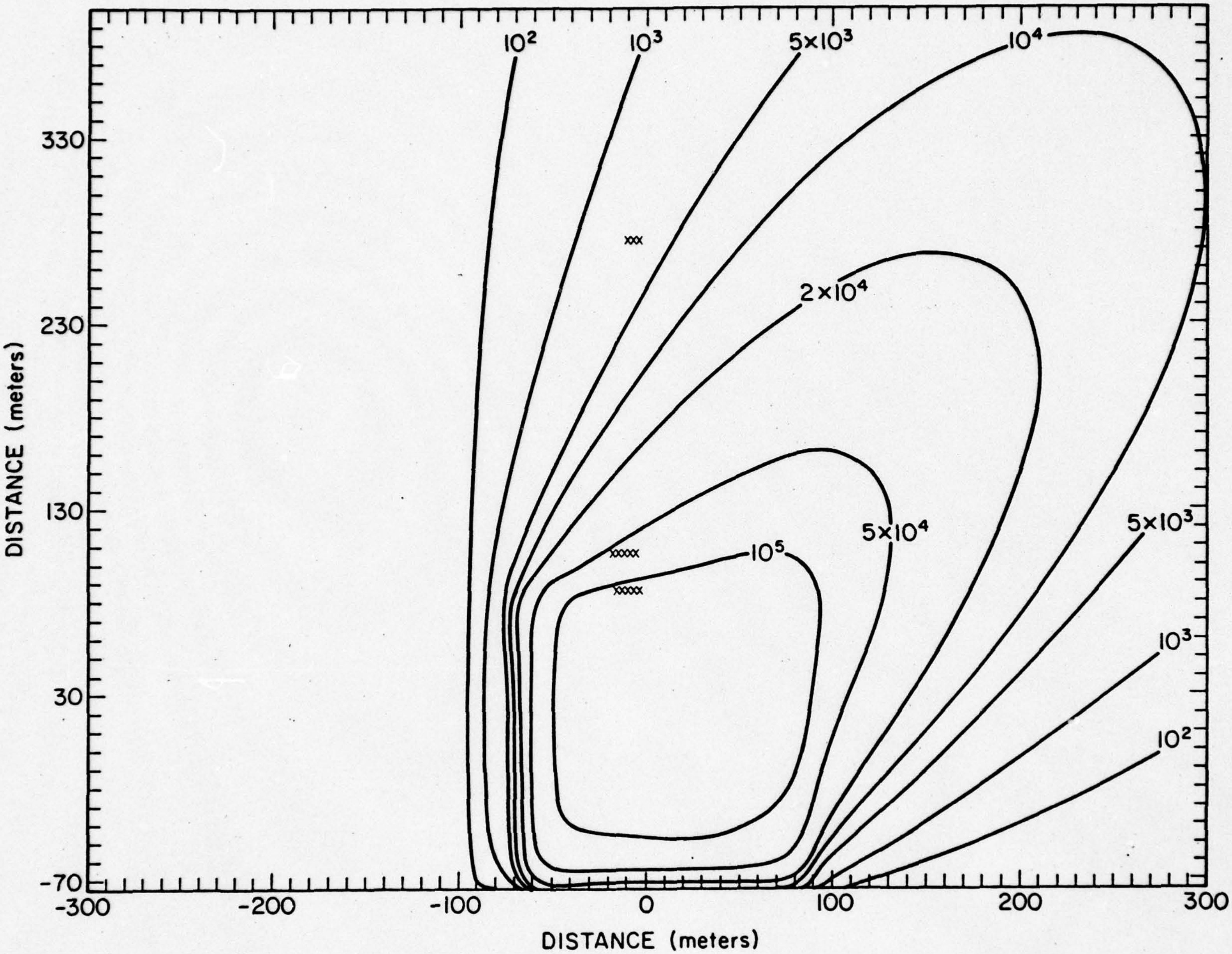

FIGURE 4-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 4 of the 1976 Deer Creek Lake Trials.

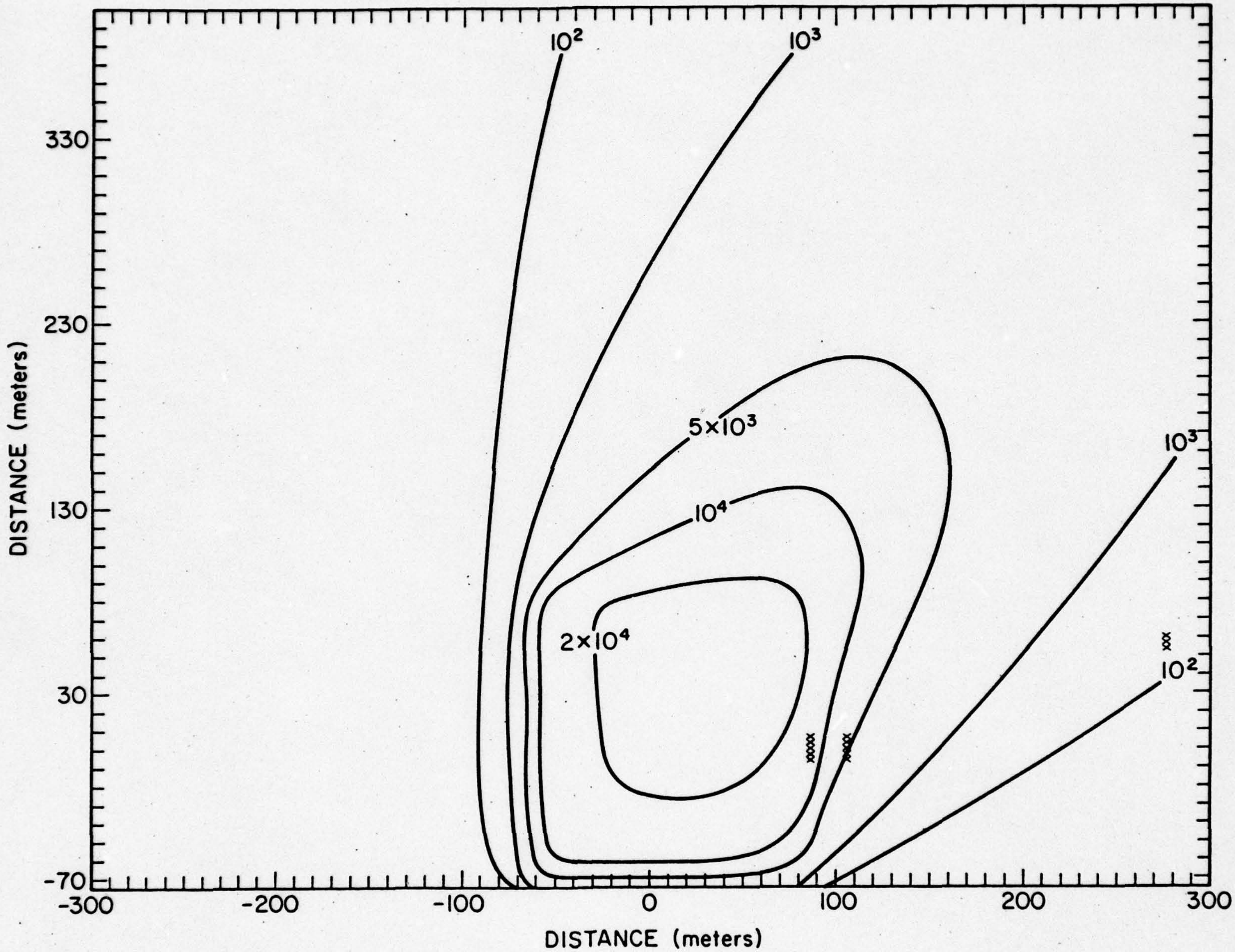

FIGURE 5-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 6 of the 1976 Deer Creek Lake Trials.

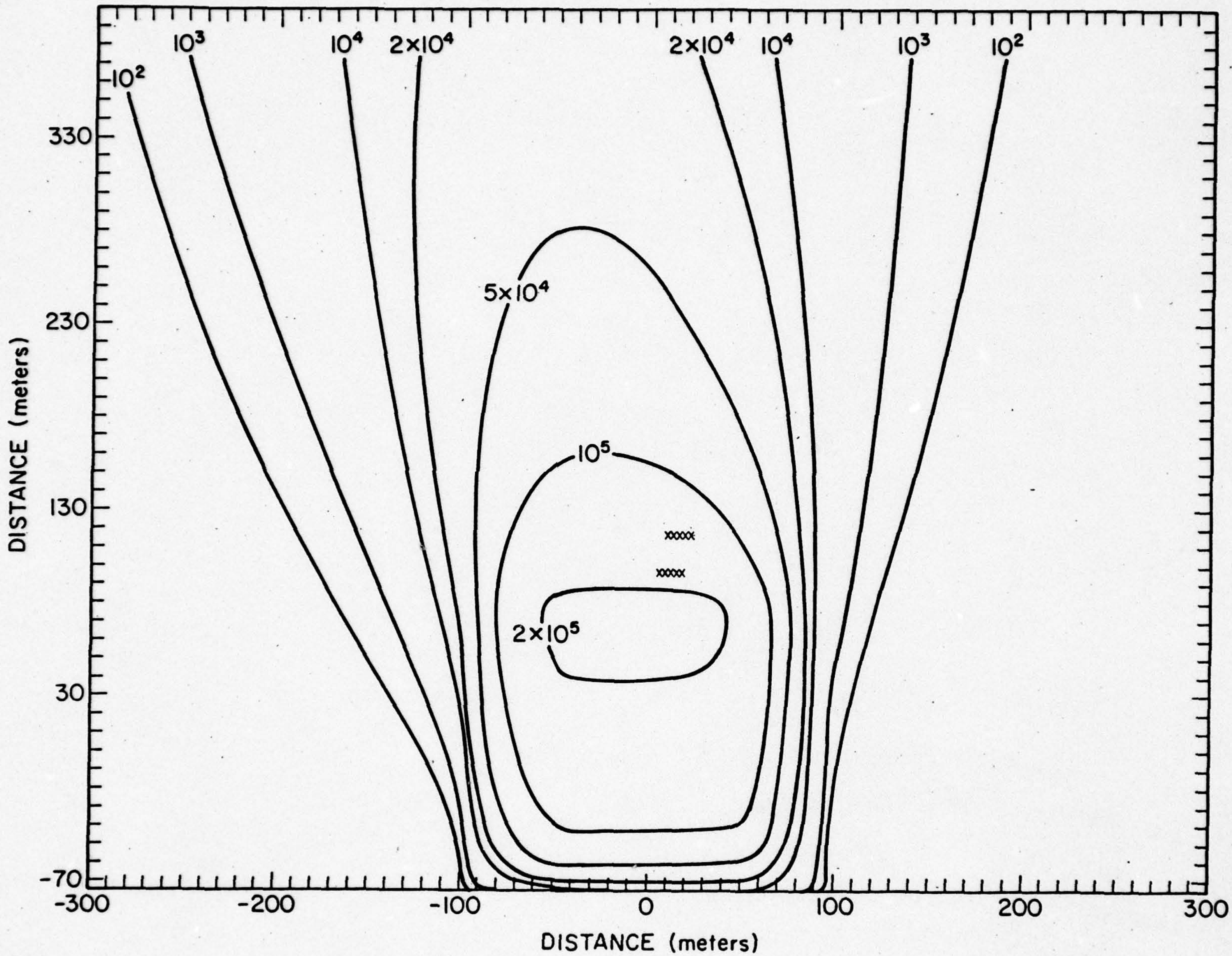

FIGURE 6-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 7 of the 1976 Deer Creek Lake Trials.

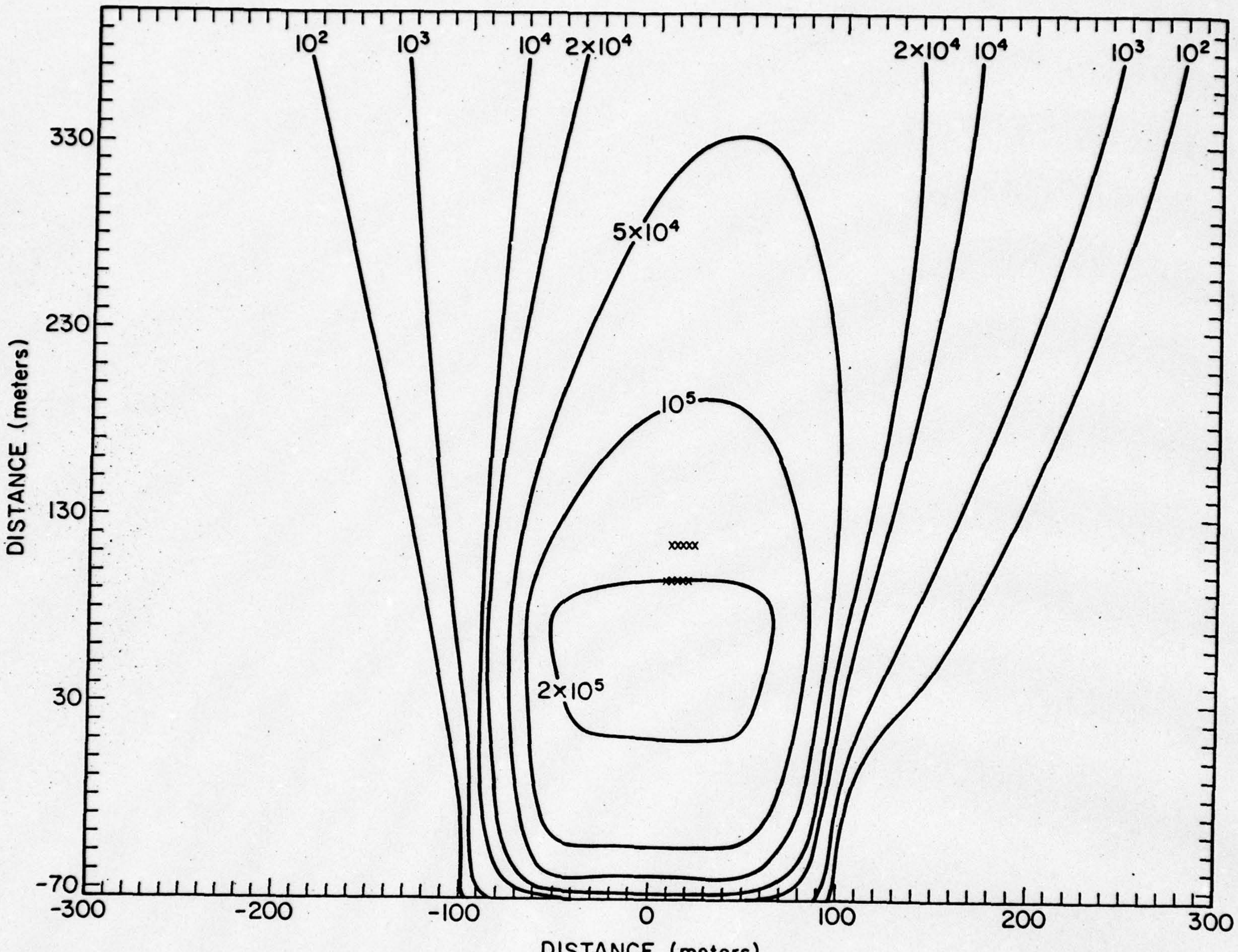

FIGURE 7-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 8 of the 1976 Deer Creek Lake Trials.

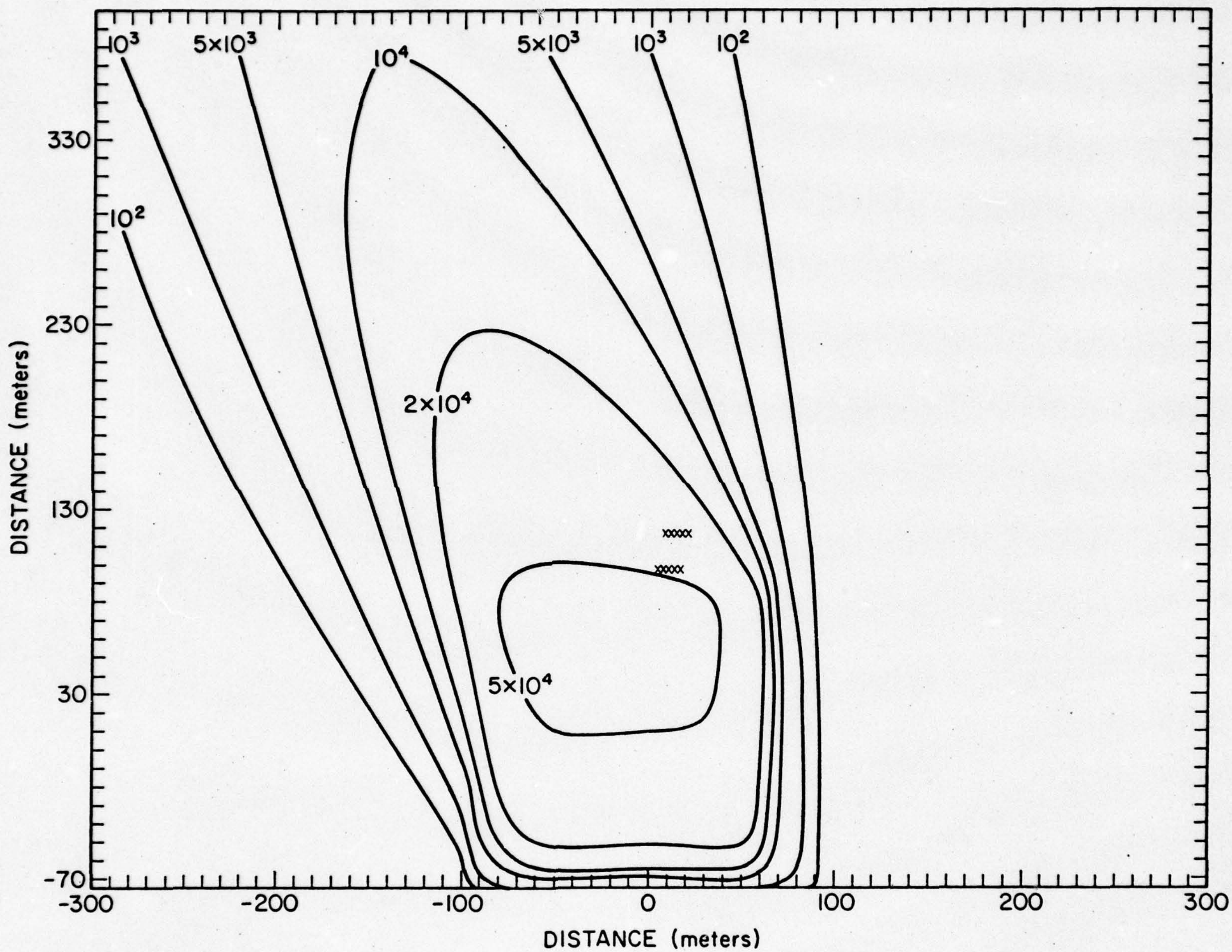

FIGURE 8-D. Isopleths of ground-level dye concentrations in units of nanograms per cubic meter for Run Number 9 of the 1976 Deer Creek Lake Trials.

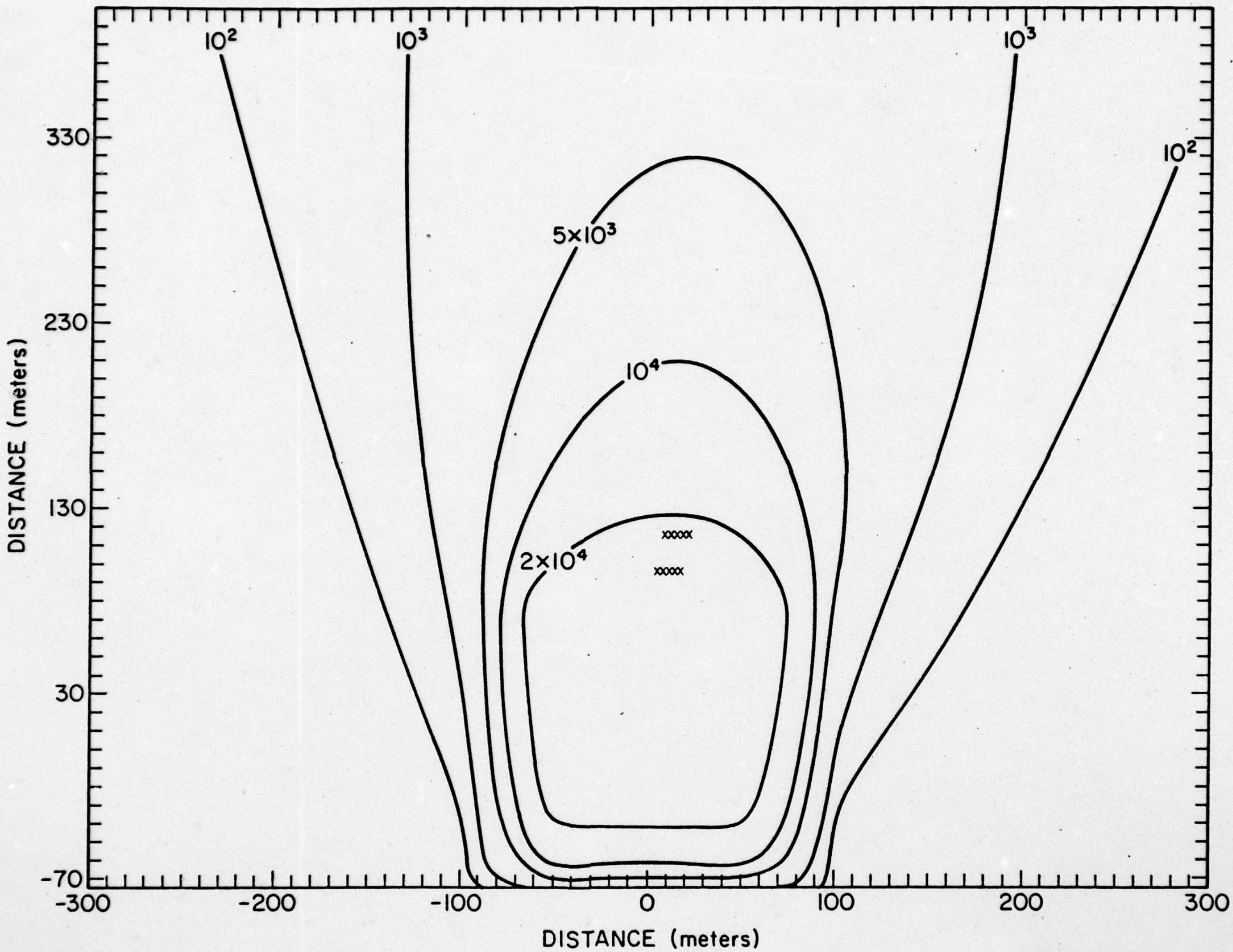

FIGURE 9-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 10 of the 1976 Deer Creek Lake Trials.

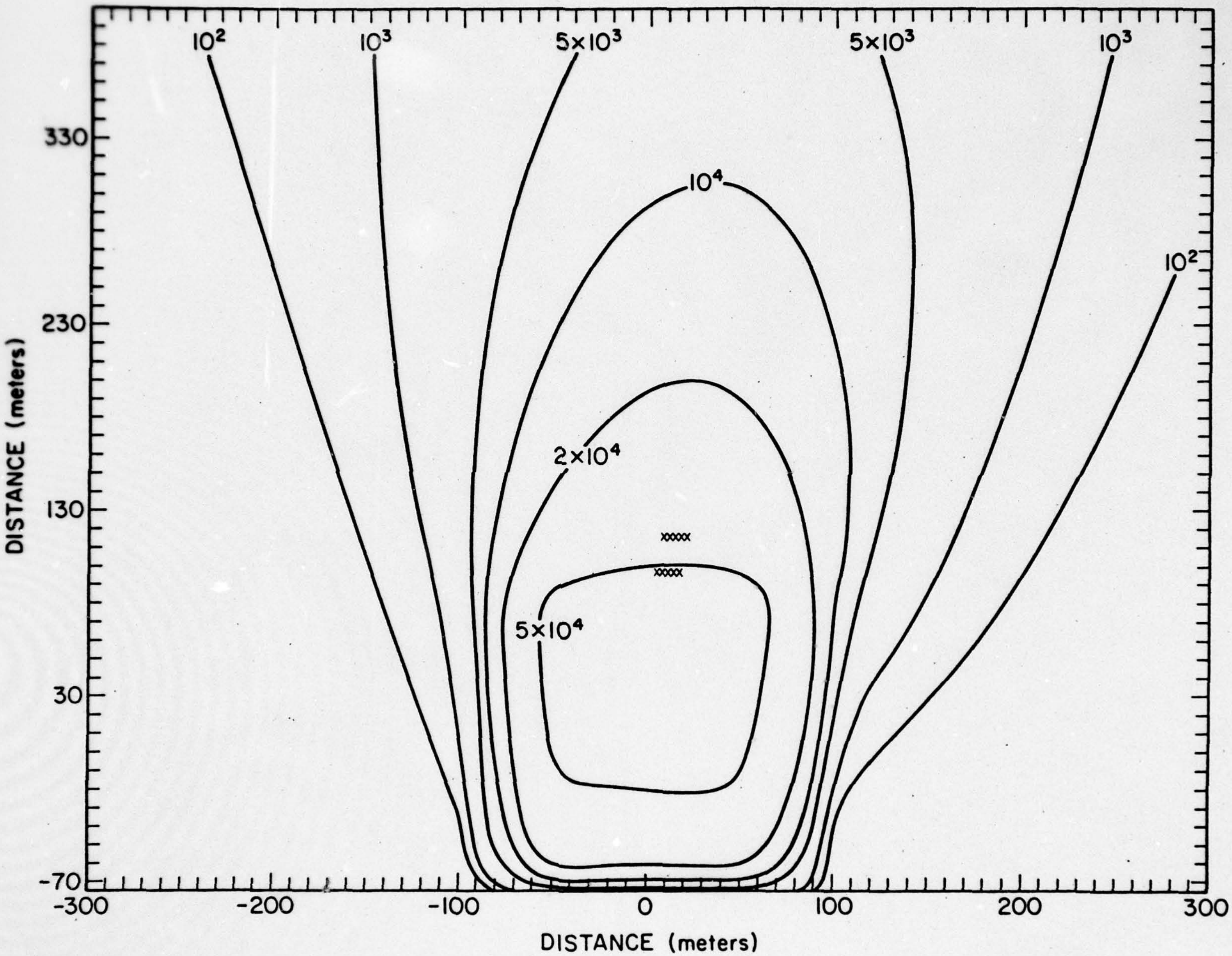

FIGURE 10-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 11 of the 1976 Deer Creek Lake Trials.

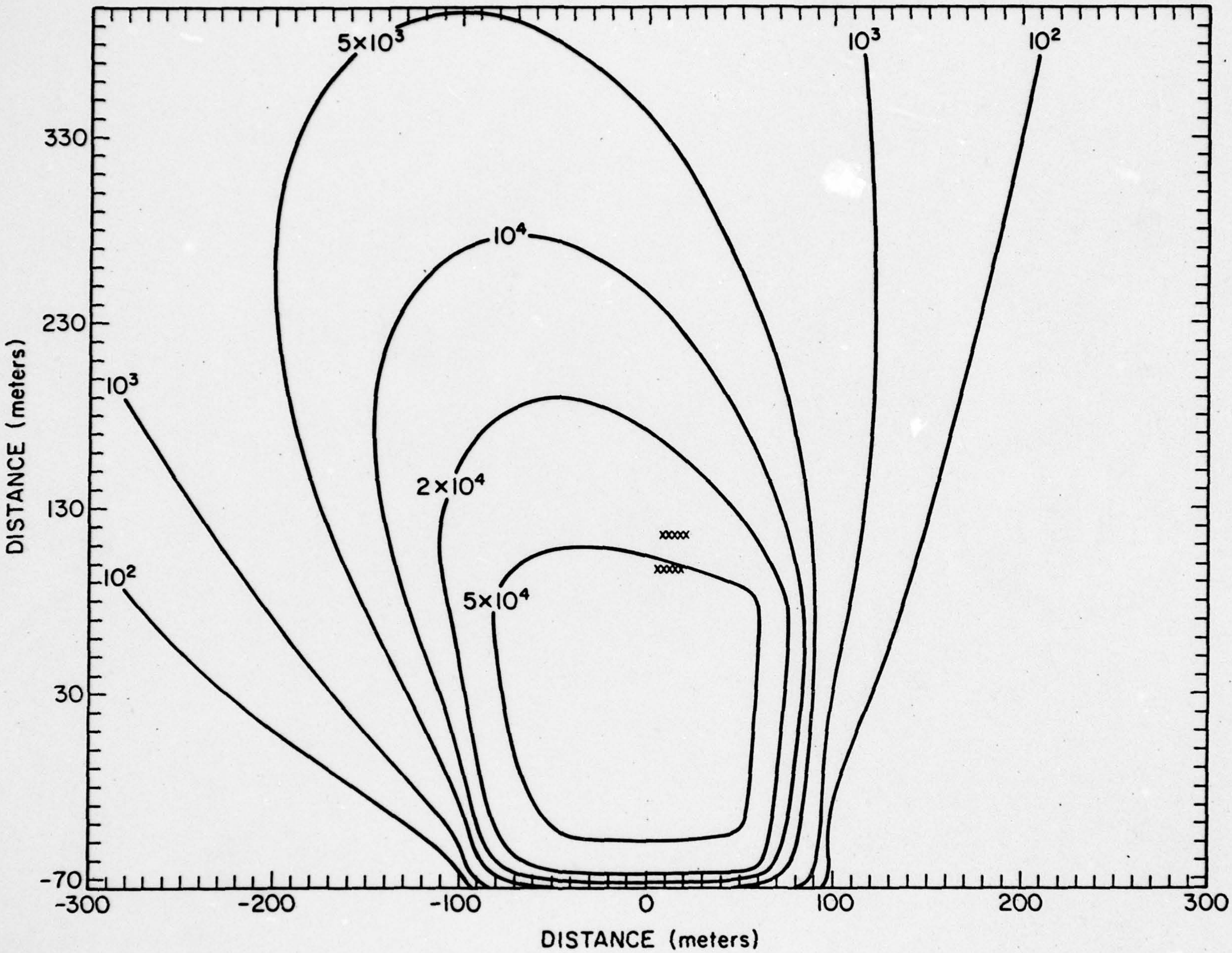

FIGURE 11-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 12 of the 1976 Deer Creek Lake Trials.

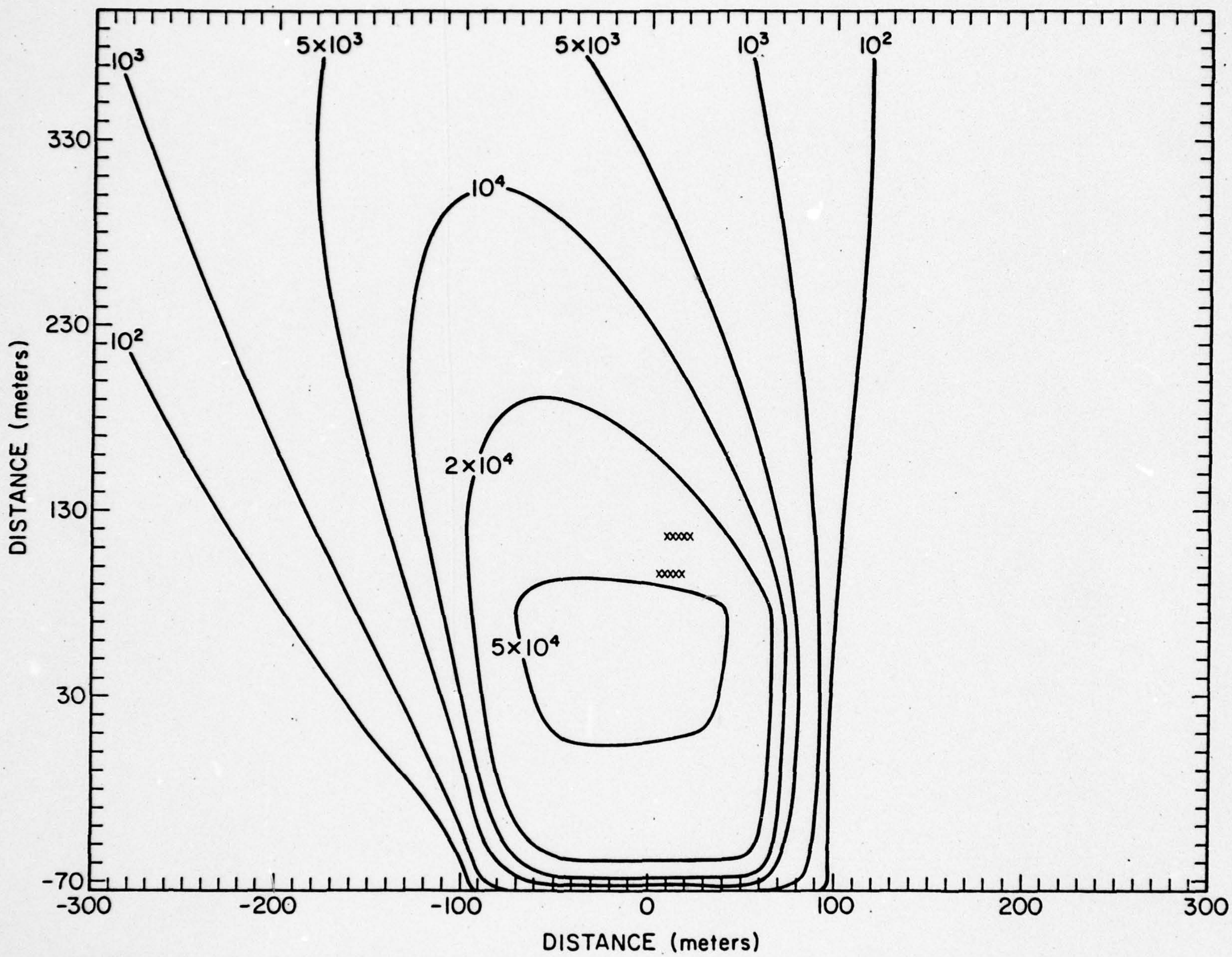

FIGURE 12-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 13 of the 1976 Deer Creek Lake Trials.

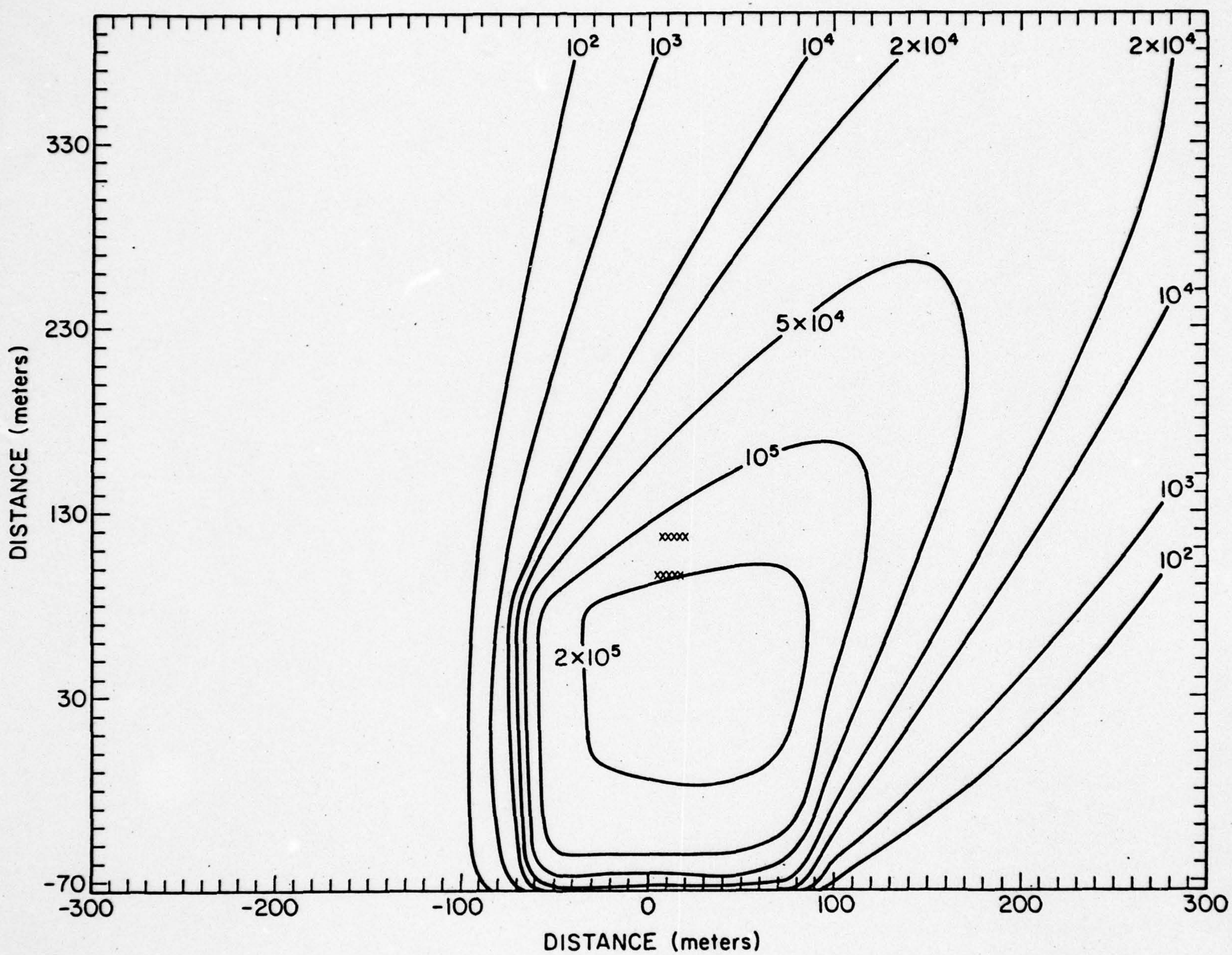

FIGURE 13-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 14 of the 1976 Deer Creek Lake Trials.

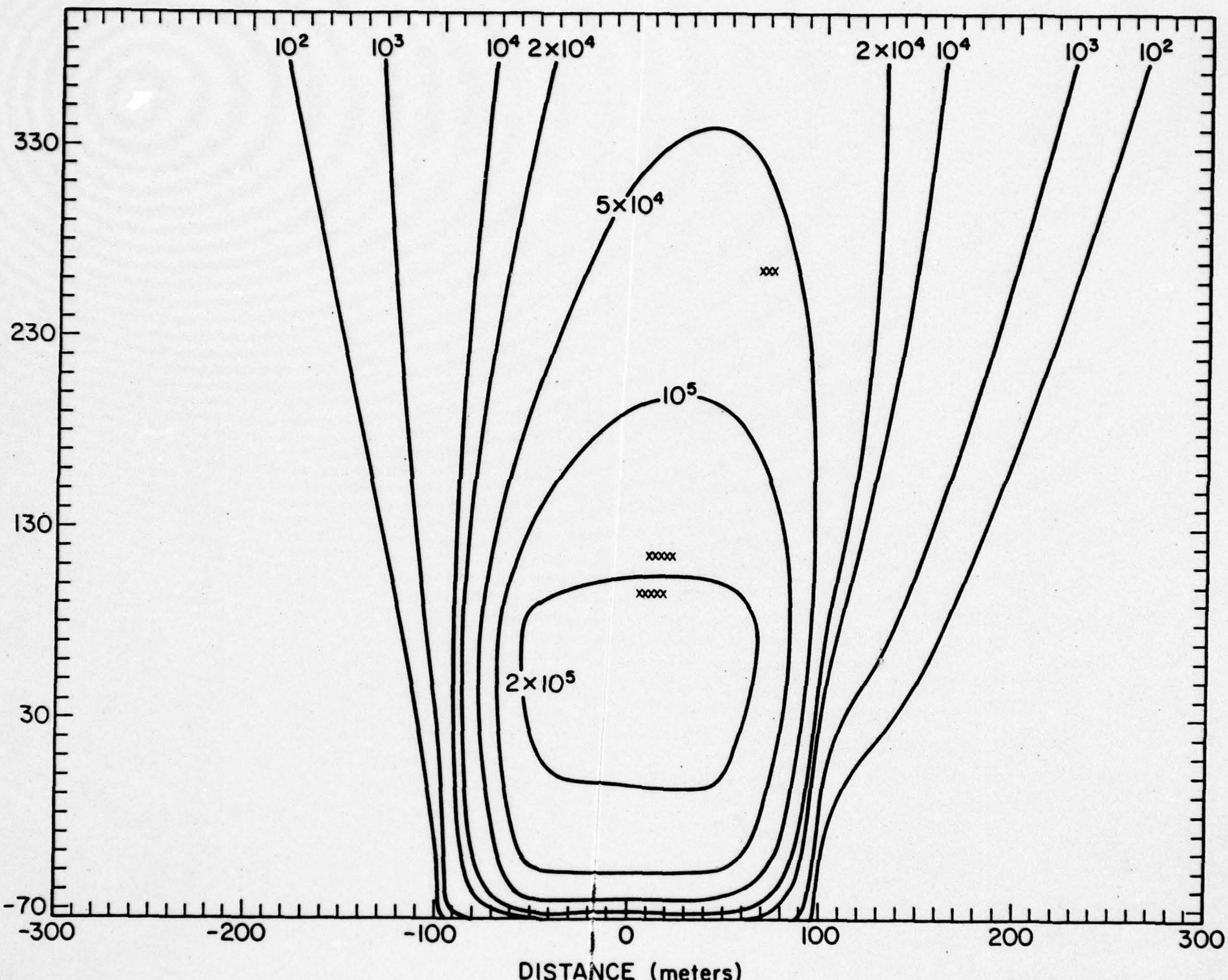

FIGURE 14-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 15 of the 1976 Deer Creek Lake Trials.

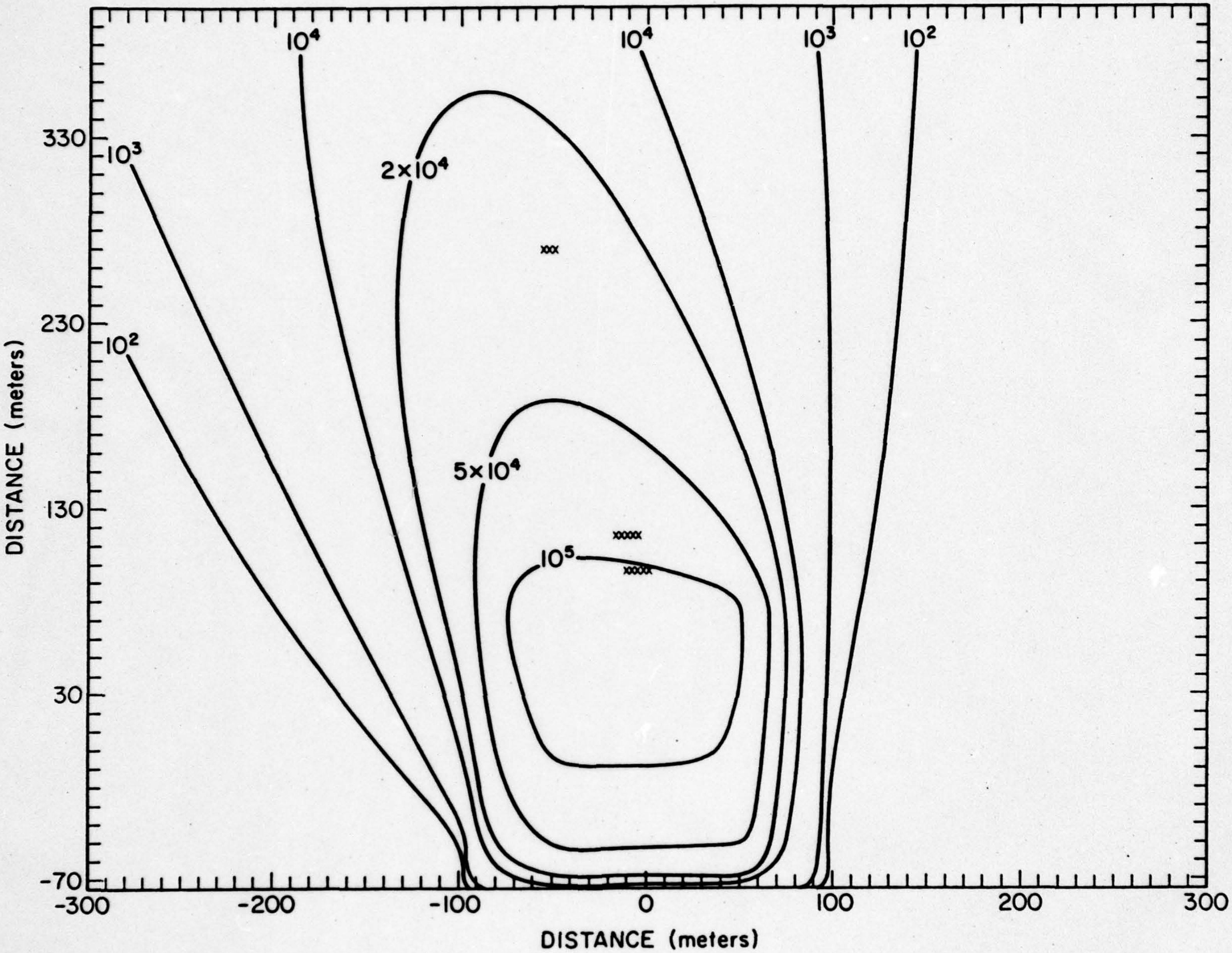

FIGURE 15-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 16 of the 1976 Deer Creek Lake Trials.

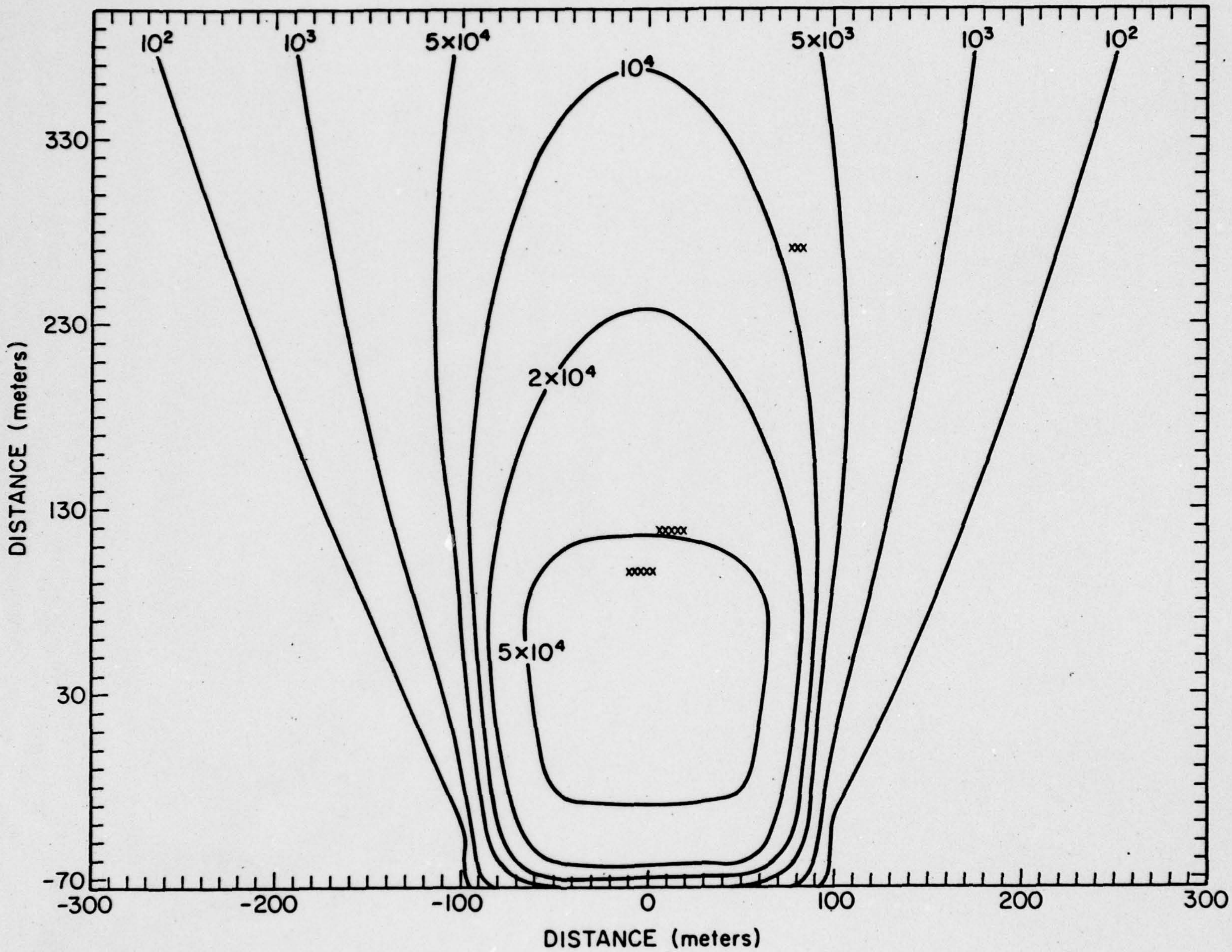

FIGURE 16-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 17 of the 1976 Deer Creek Lake Trials.

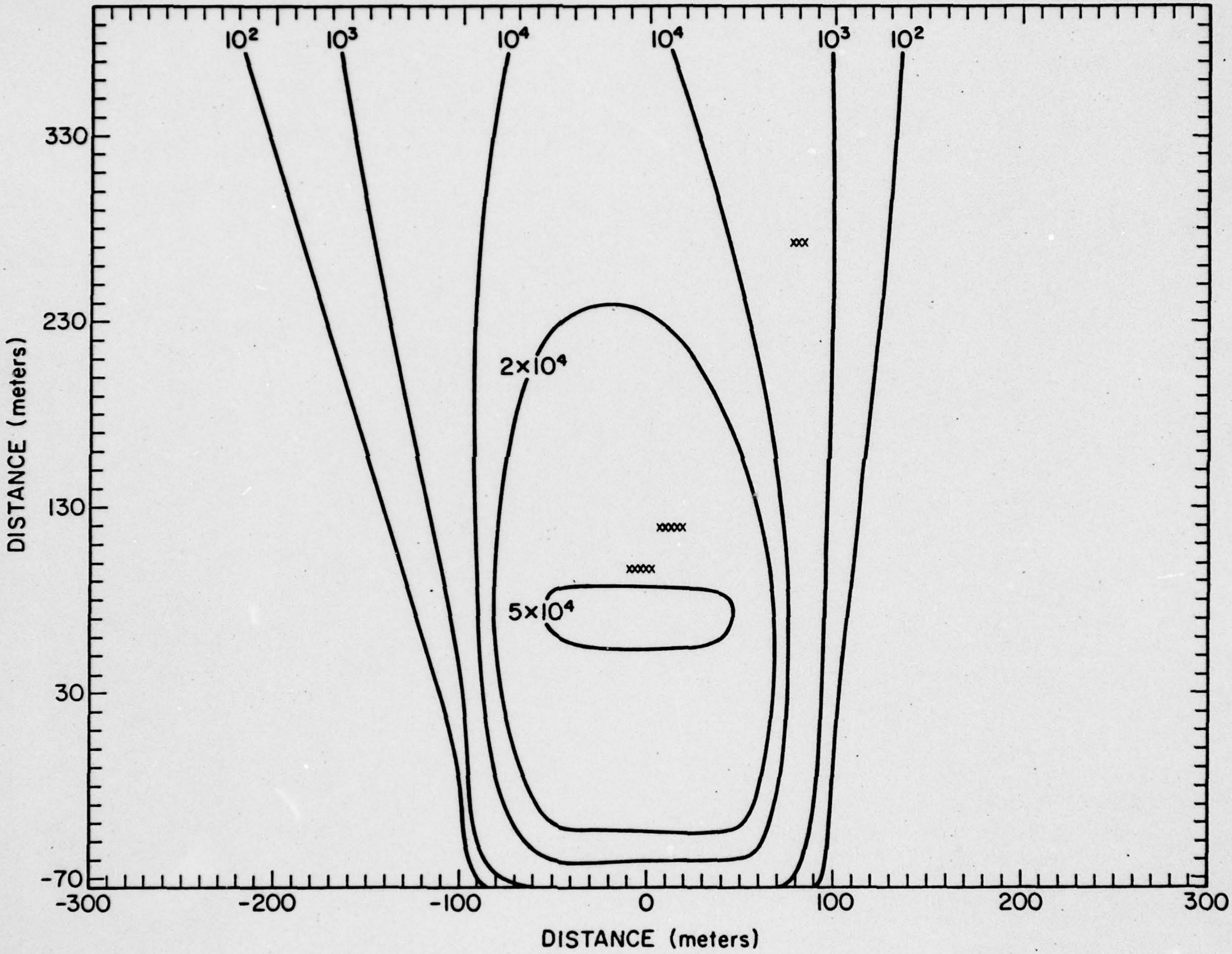

FIGURE 17-D. Isopleths of ground-level dye concentrations in units of nanograms per cubic meter for Run Number 18 of the 1976 Deer Creek Lake Trials.

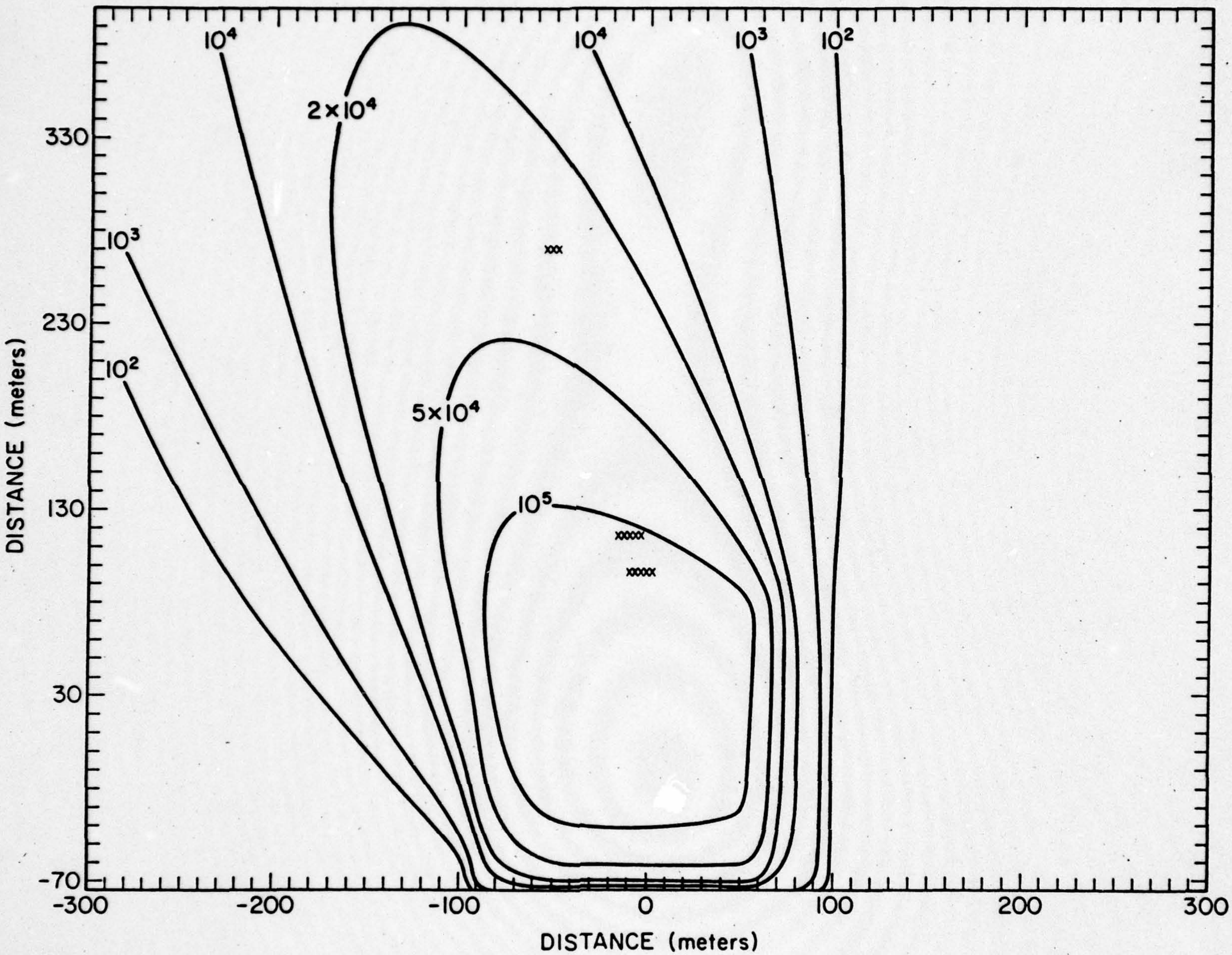

FIGURE 18-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 19 of the 1976 Deer Creek Lake Trials.

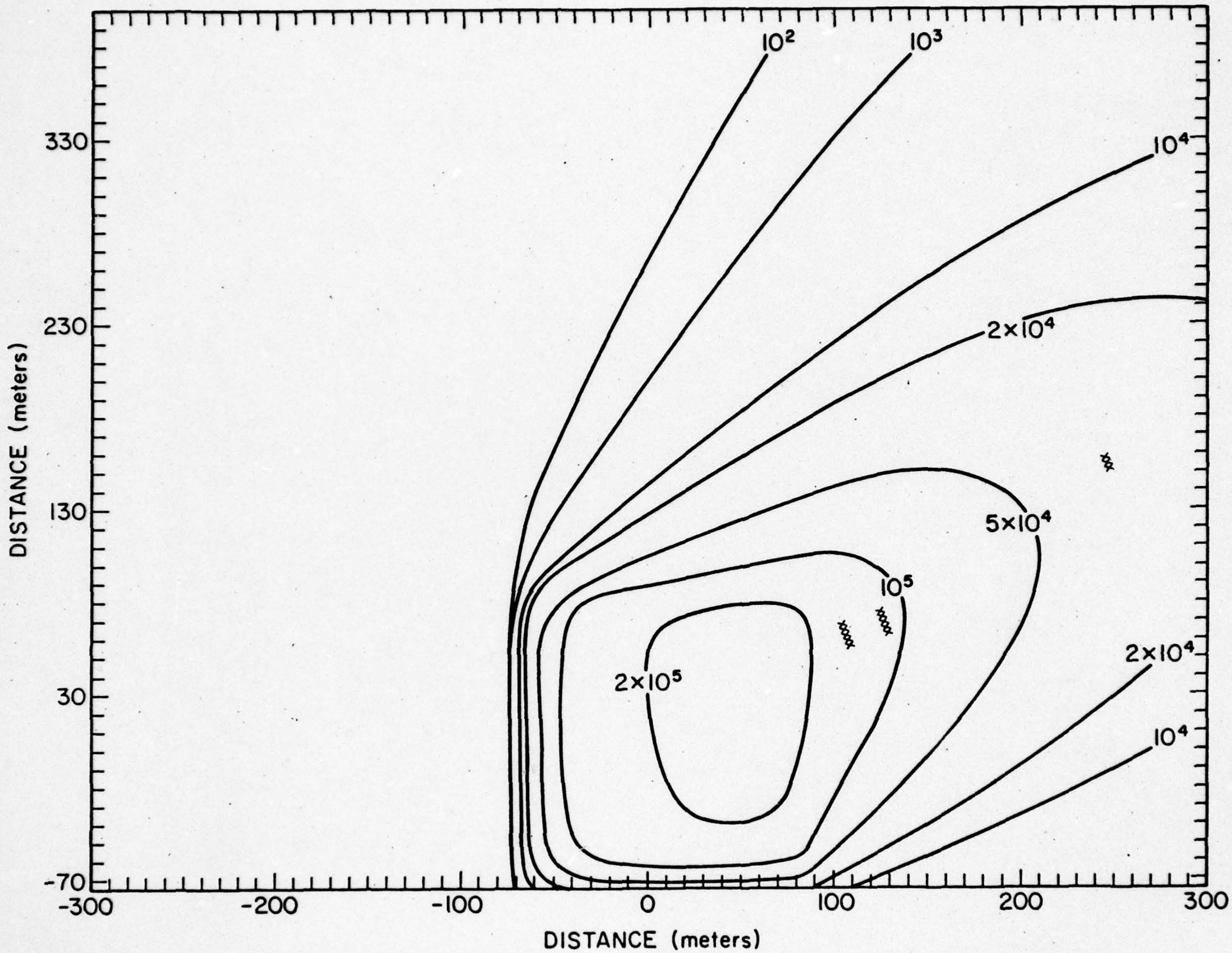

FIGURE 19-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 20 of the 1976 Deer Creek Lake Trials.

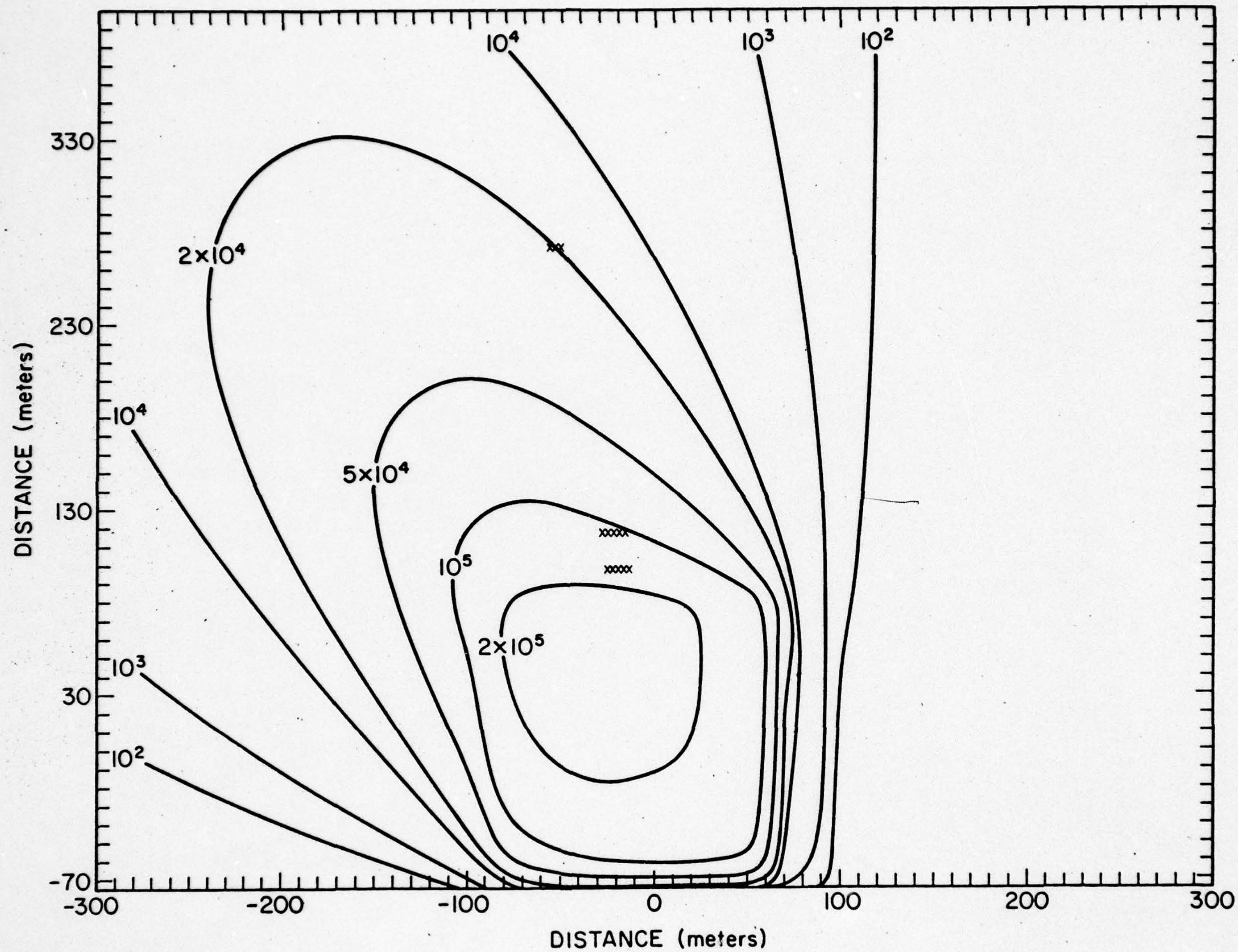

FIGURE 20-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 21 of the 1976 Deer Creek Lake Trials.

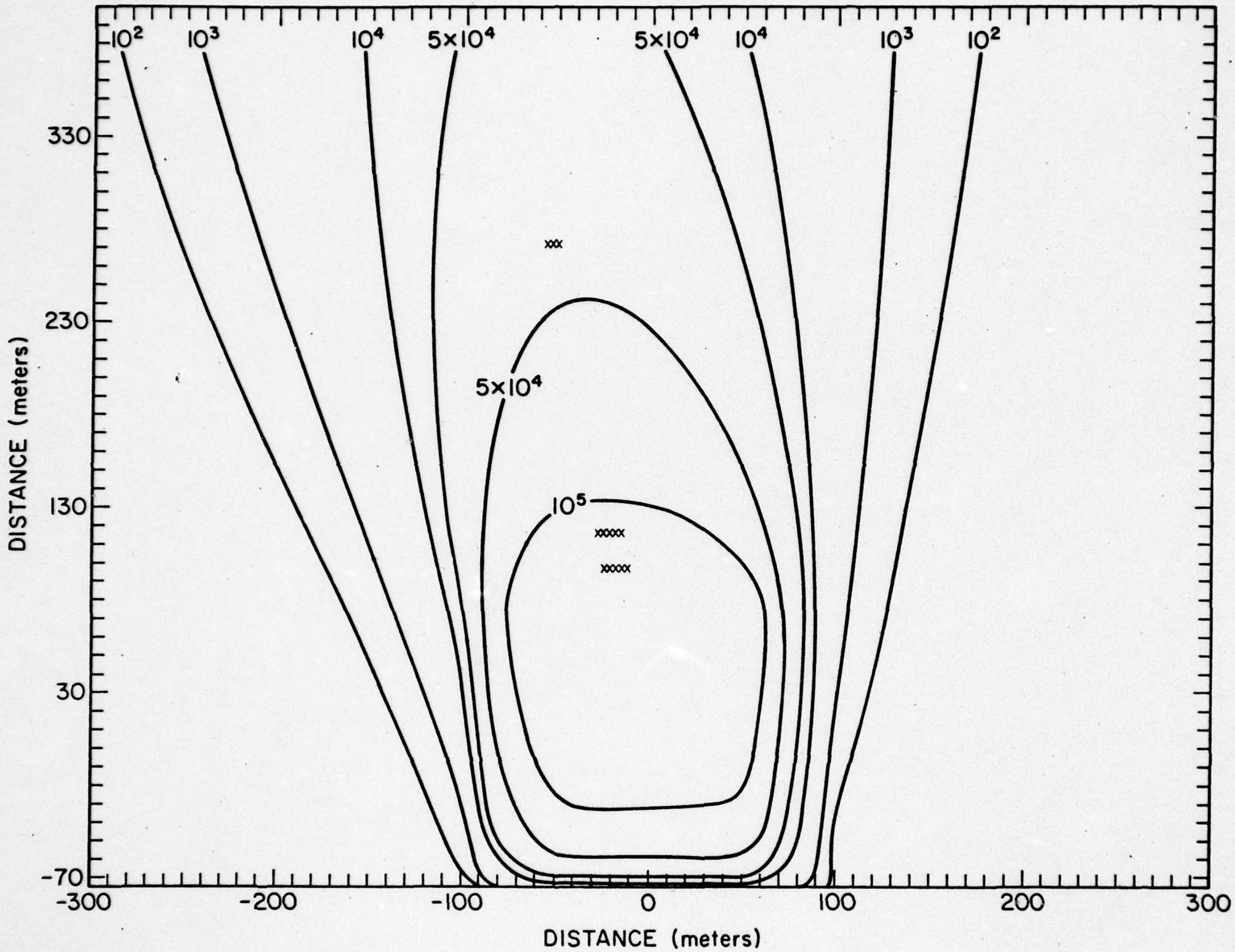

FIGURE 21-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 22 of the 1976 Deer Creek Lake Trials.

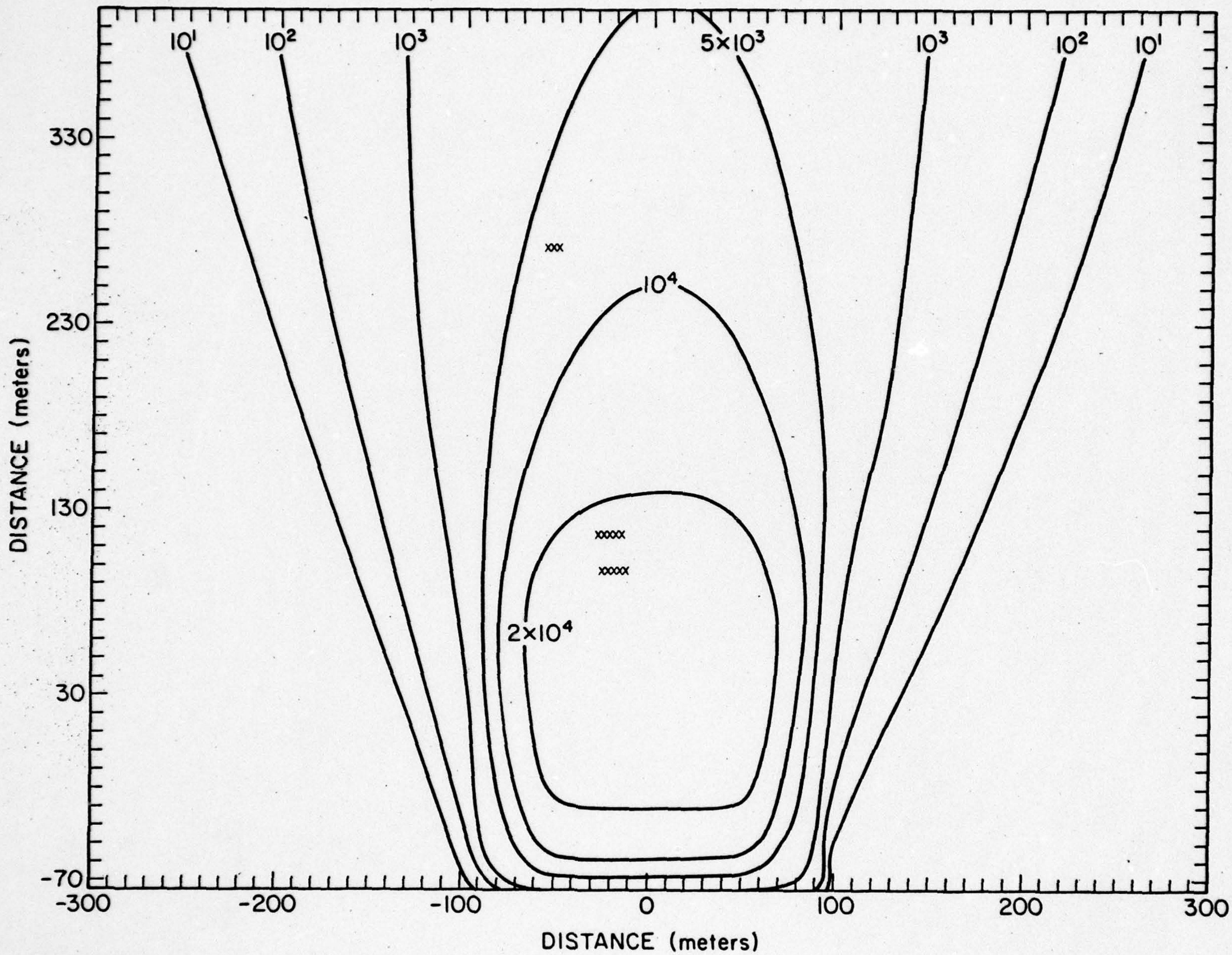

FIGURE 22-D. Isopleths of ground-level dye concentrations in units of nanograms per cubic meter for Run Number 23 of the 1976 Deer Creek Lake Trials.

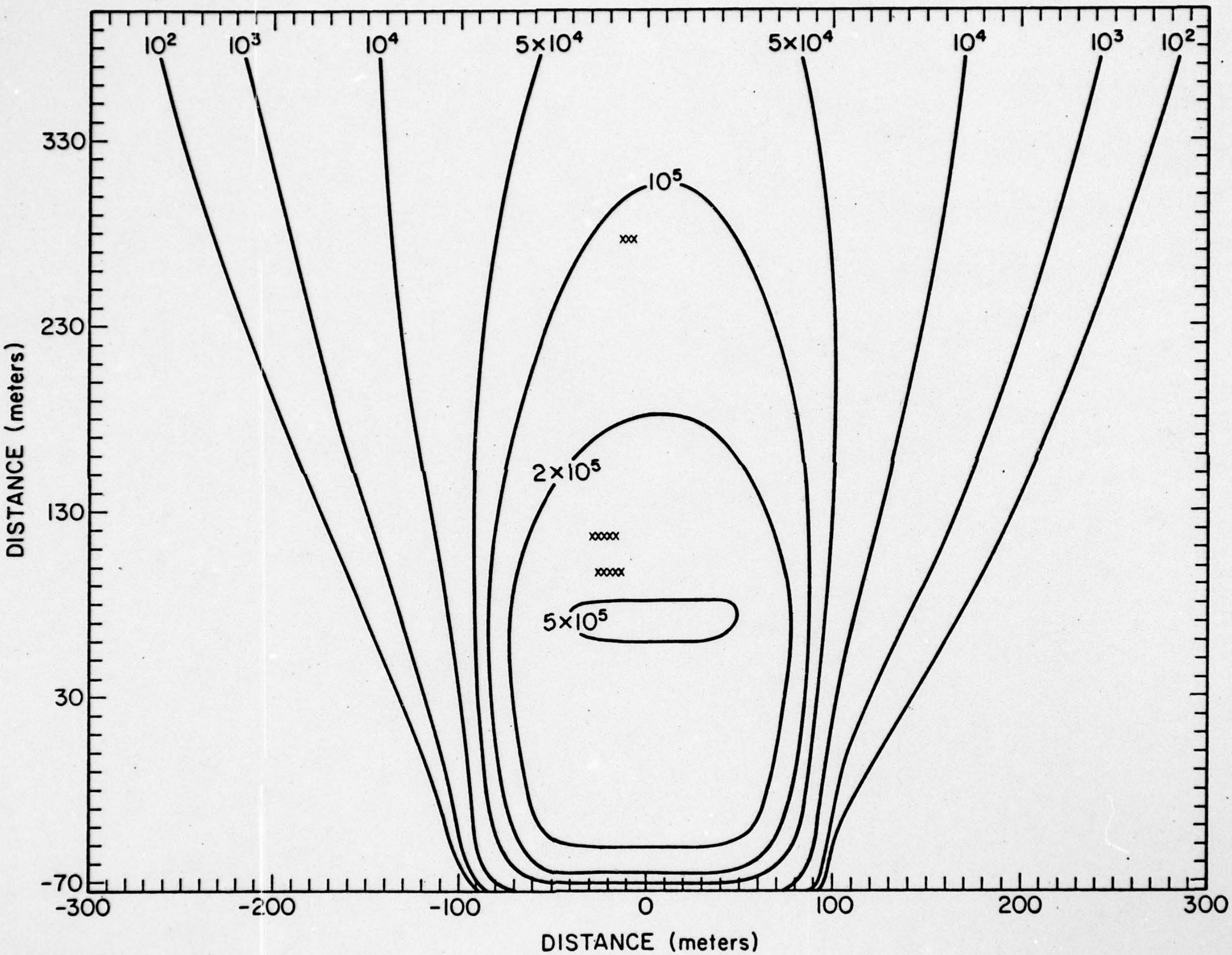

FIGURE 23-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 24 of the 1976 Deer Creek Lake Trials.

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FEB 78 R K DUMBAULD, H E CRAMER DAMD17-77-C-7048
UNCLASSIFIED TR-78-124-01 NL

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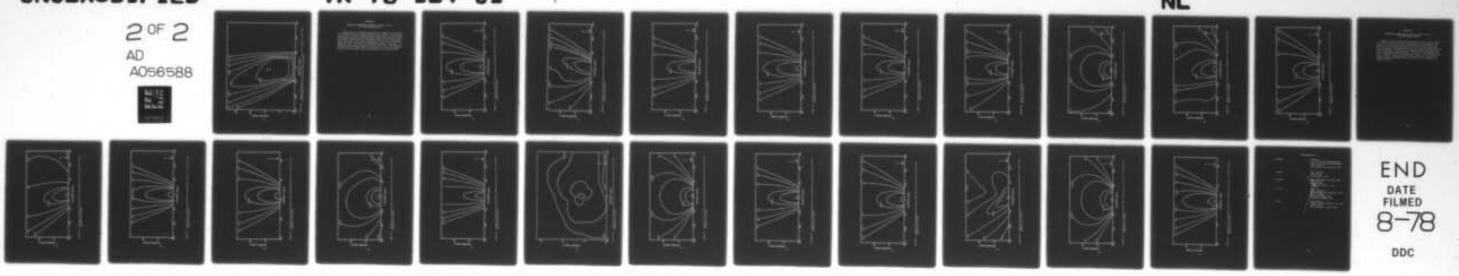

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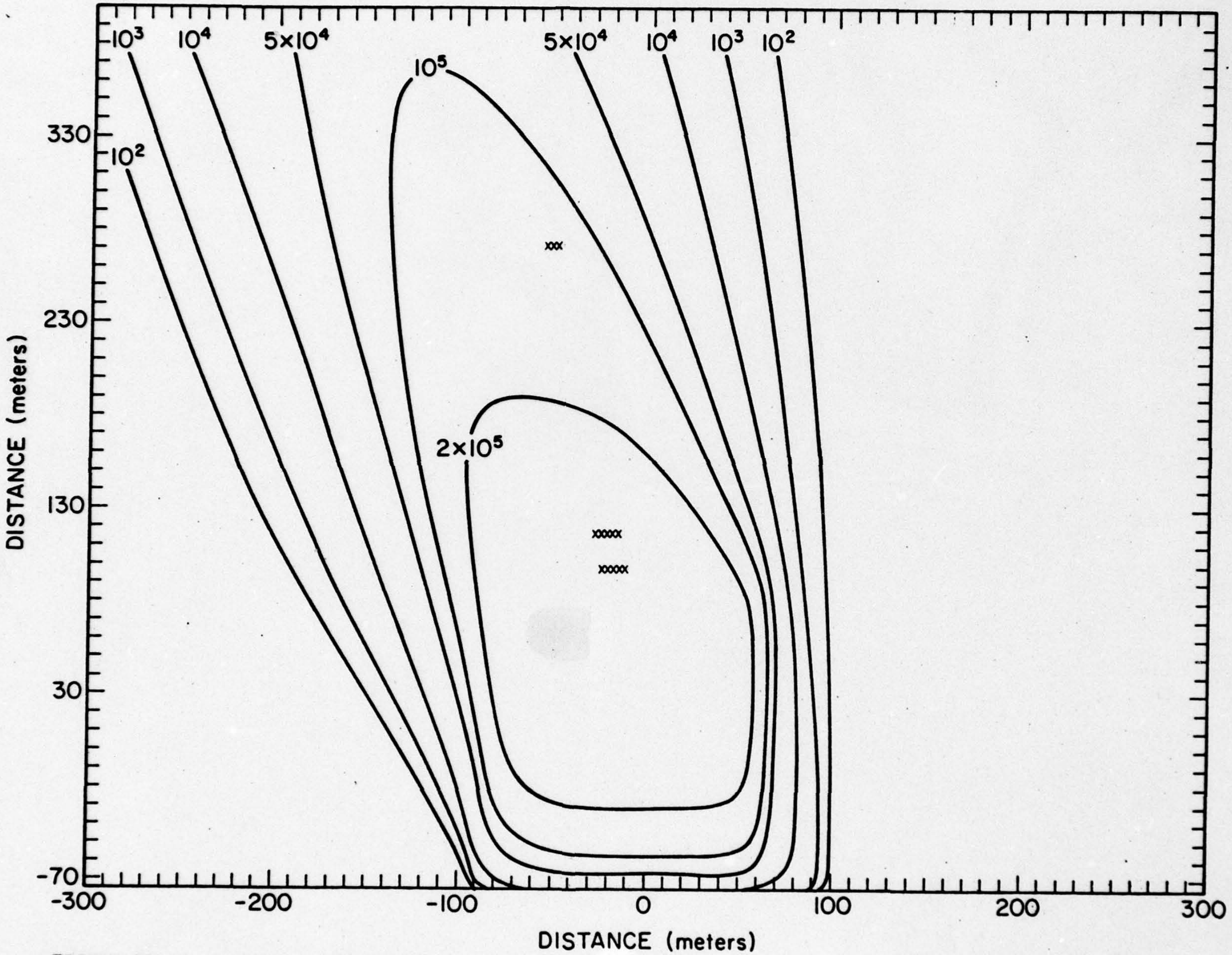

FIGURE 24-D. Isopleths of ground-level concentration in units of viable counts per cubic meter for Run Number 25 of the 1976 Deer Creek Lake Trials.

APPENDIX E

NORMALIZED CONCENTRATION ISOPLETH PATTERNS FOR THE 1974 FORT HUACHUCA TRIALS

Computer plots of normalized concentration isopleths for 9 of the 1974 Fort Huachuca trials are presented in this appendix. The abscissa of each plot is lateral distance from the single spray head used in each trial and the ordinate is oriented along the mean wind direction during the sampling period, with zero representing the location of the spray head. The arrow in each figure represents the mean direction during the sampling period. The small x's show sampler positions. Absolute values of concentration in source units per cubic meter can be obtained by multiplying the values shown in the figures by the source strength of bacteria or dye in source units per milliliter of irrigation water.

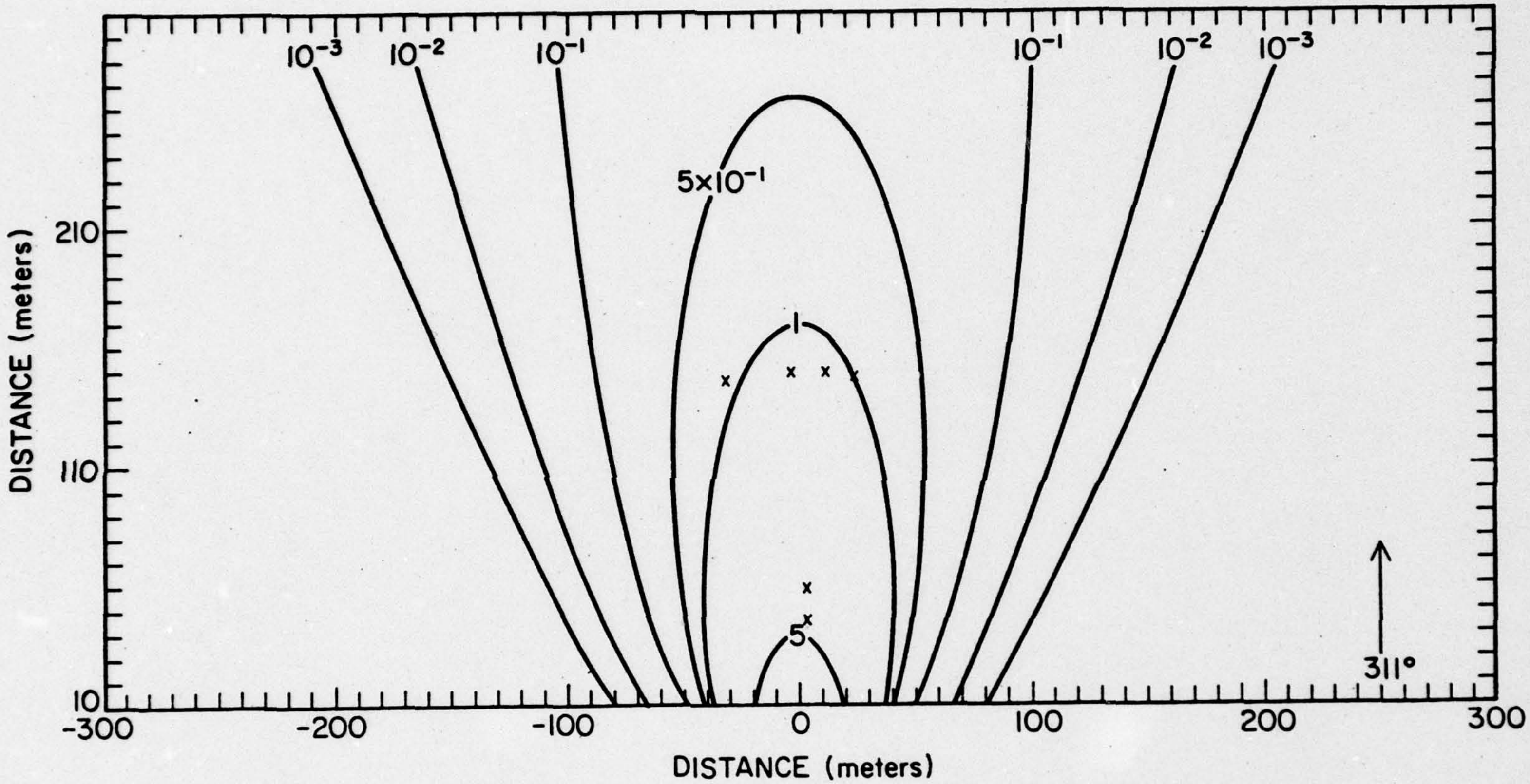

FIGURE 1-E. Isopleths of normalized ground-level concentrations for Trial 1 of the 1974 Fort Huachuca Trial Series.

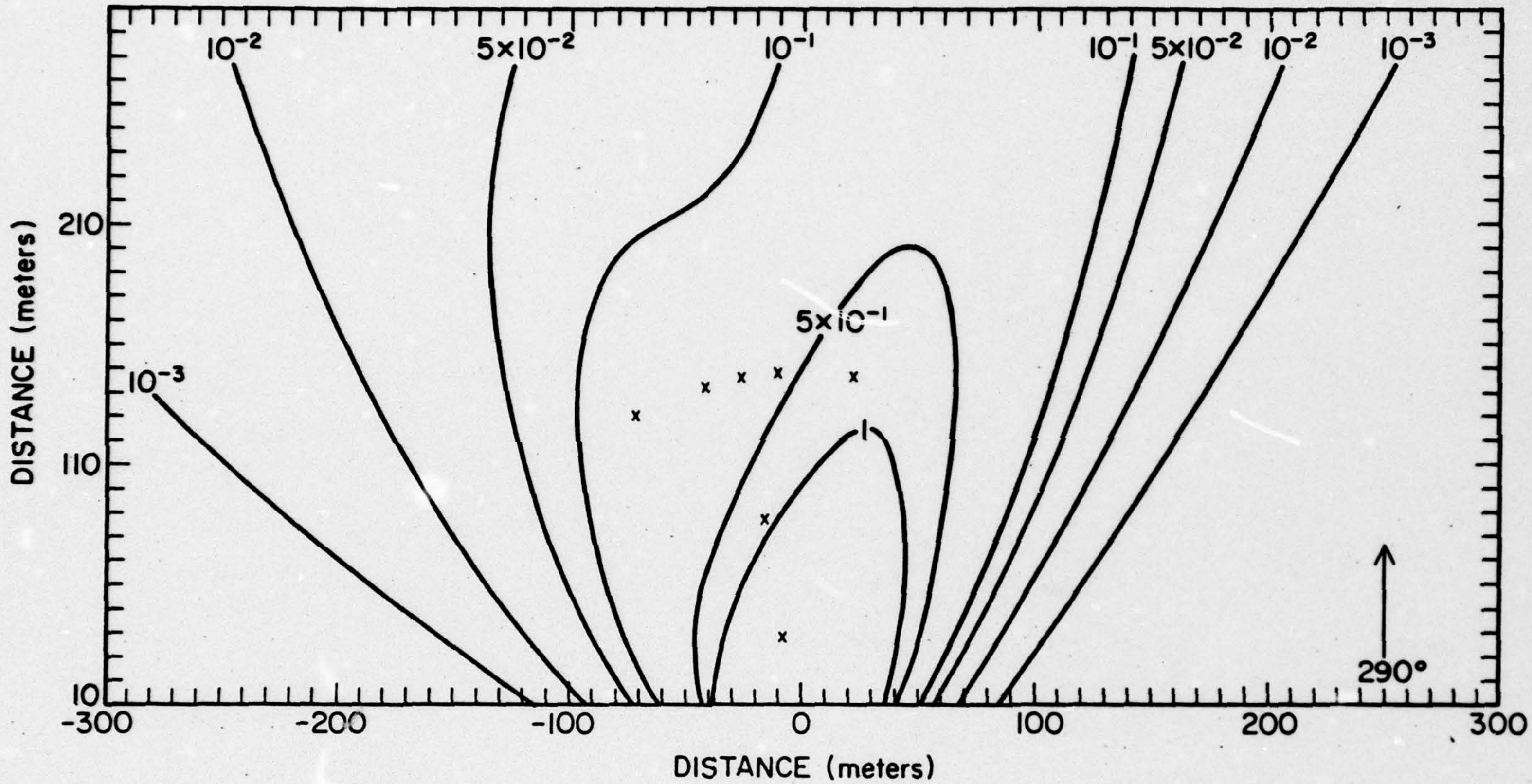

FIGURE 2-E. Isopleths of normalized ground-level concentration for Trial 2 of the 1974 Fort Huachuca Trial Series.

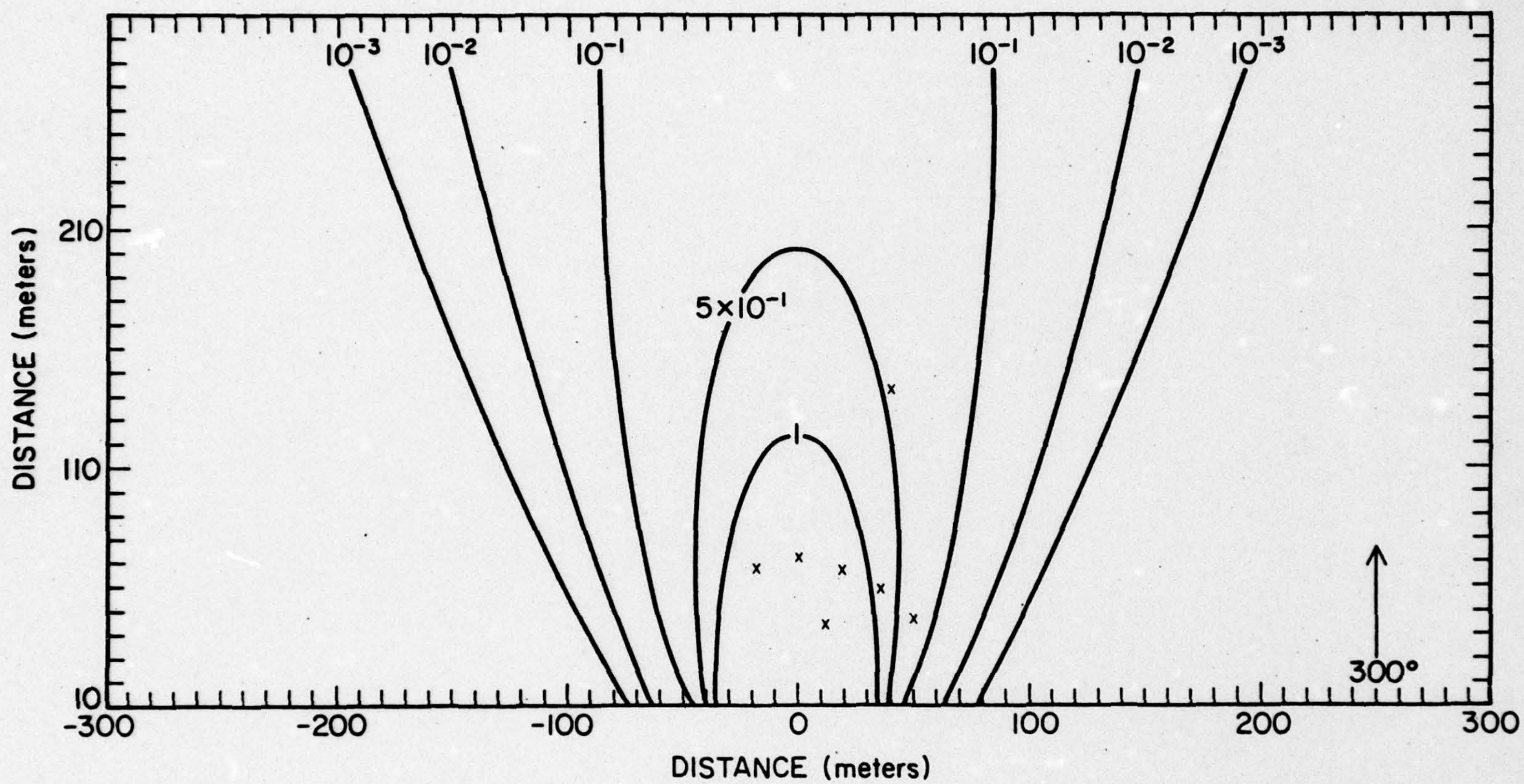

FIGURE 3-E. Isopleths of normalized ground-level concentration for Trial 7 of the 1974 Fort Huachuca Trial Series.

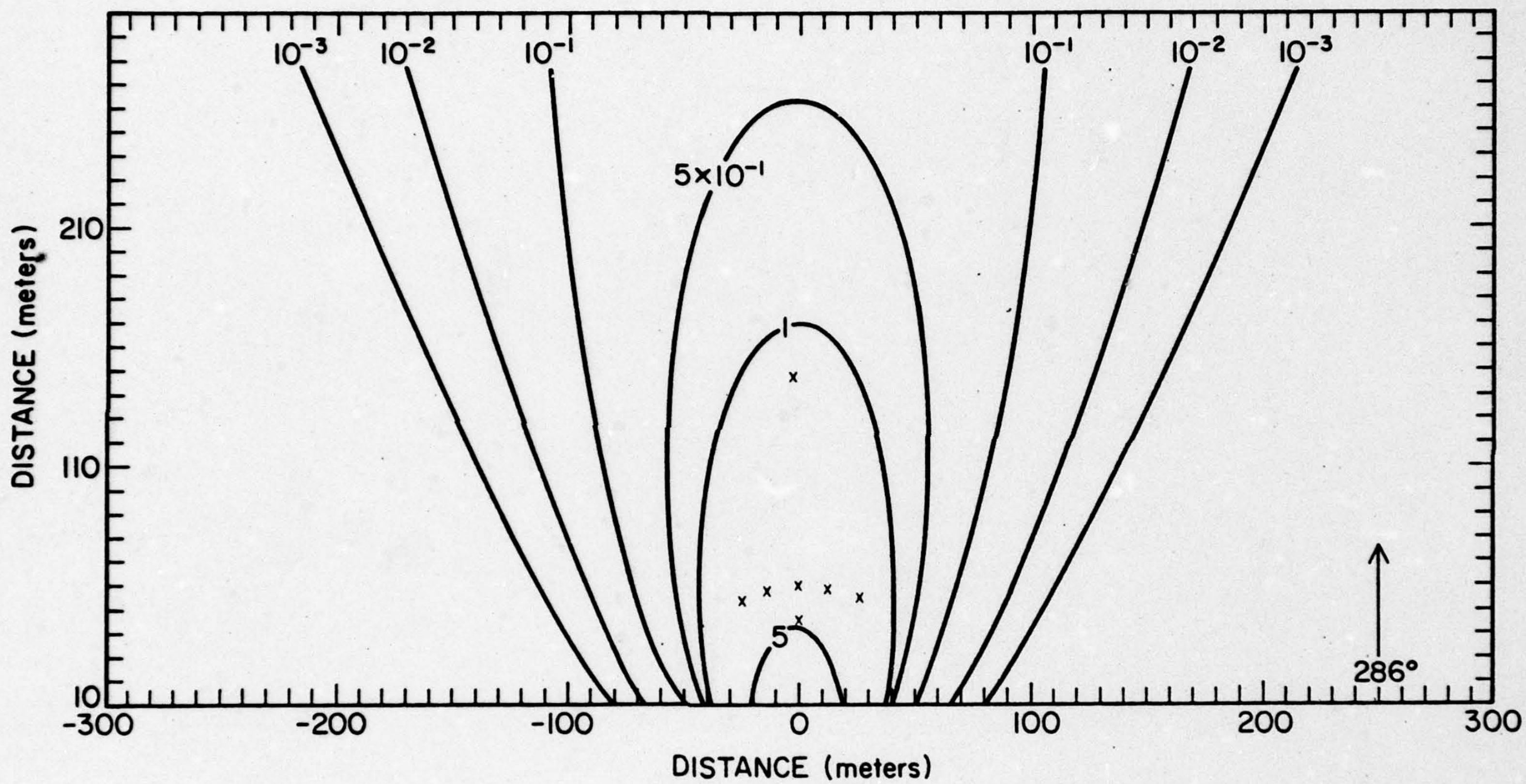

FIGURE 4-E. Isopleths of normalized ground-level concentration for Trial 8 of the 1974 Fort Huachuca Trial Series.

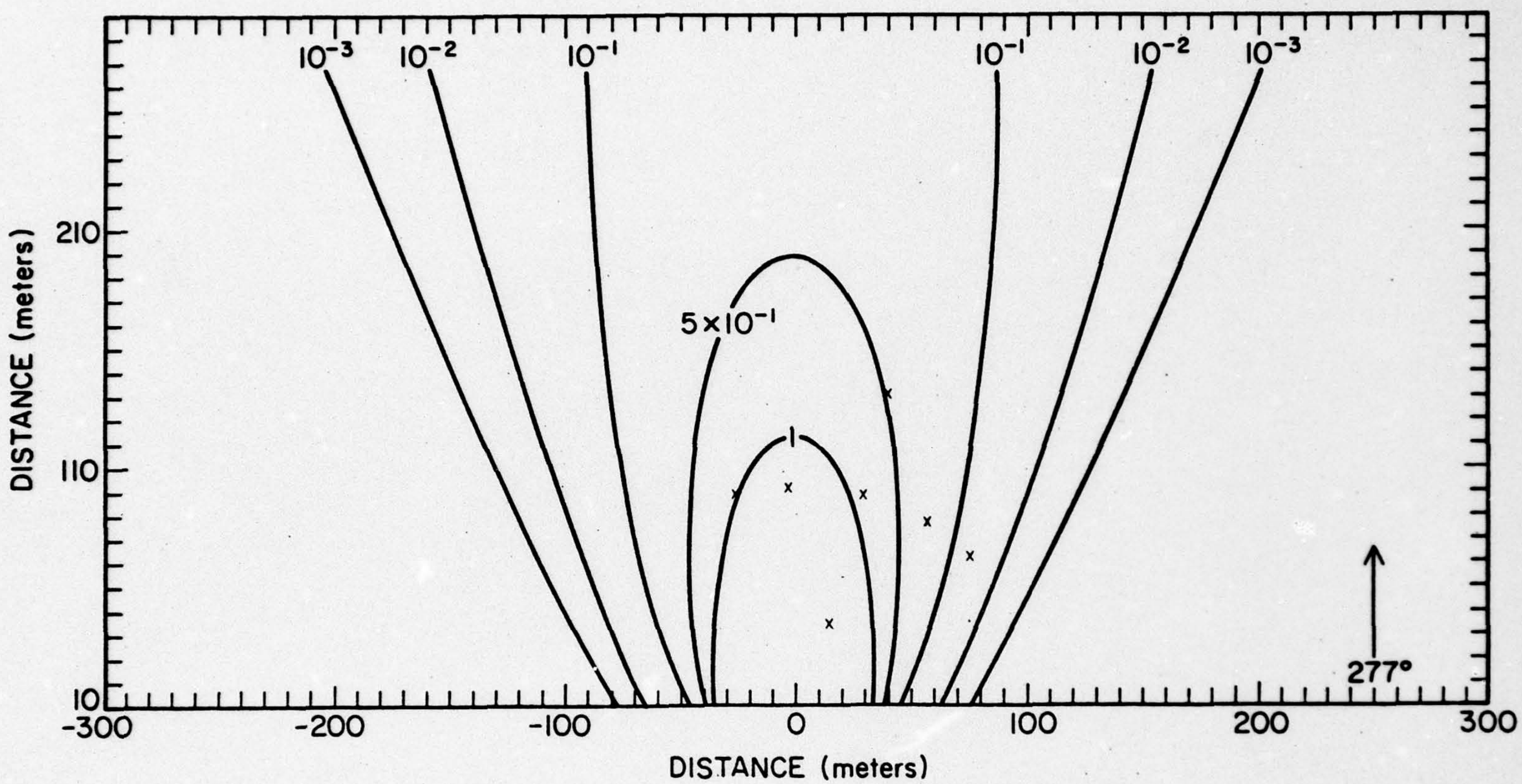

FIGURE 5-E. Isopleths of normalized ground-level concentration for Trial 9 of the 1974 Fort Huachuca Trial Series.

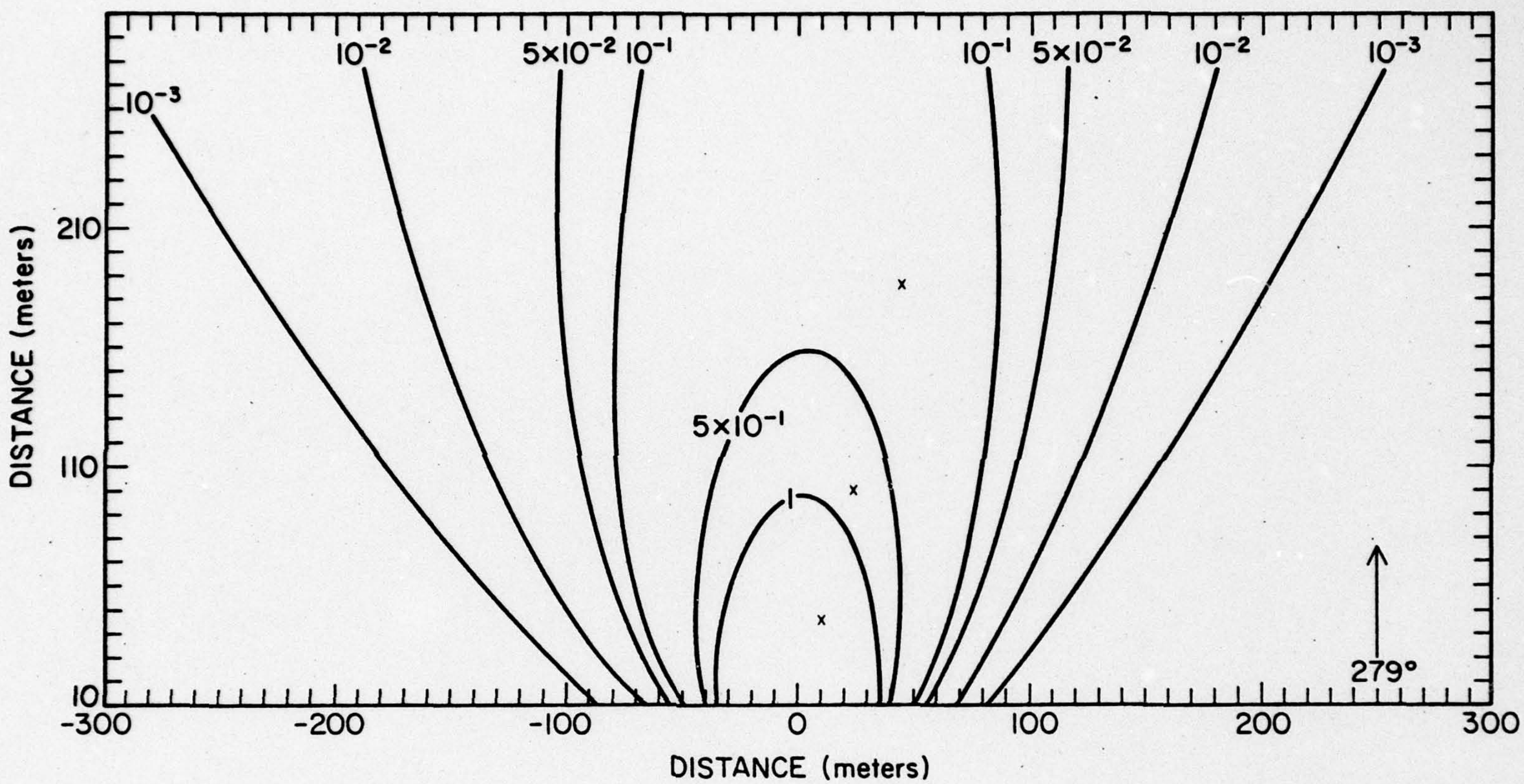

FIGURE 6-E. Isopleths of normalized ground-level concentration for Trial 10 of the 1974 Fort Huachuca Trial Series.

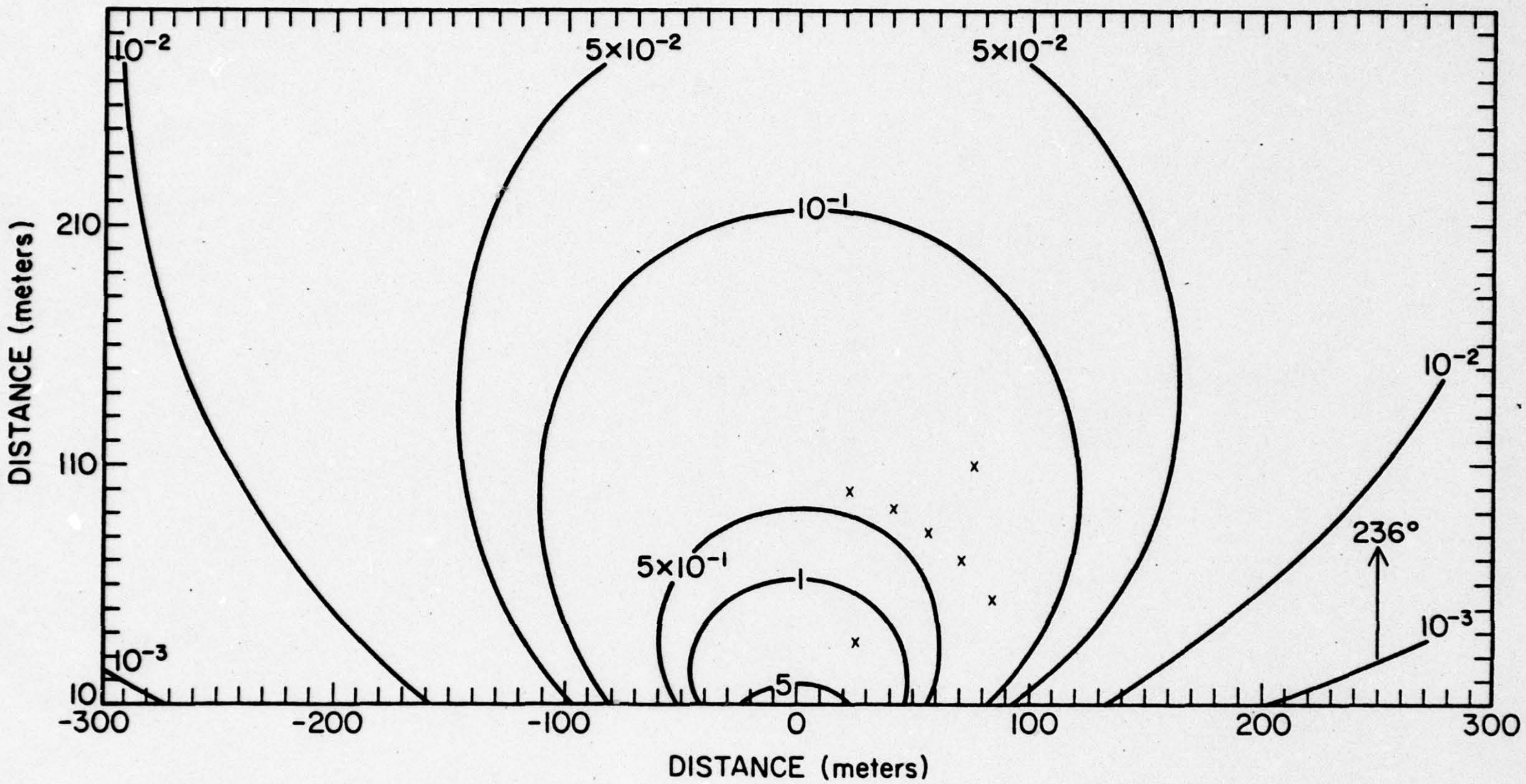

FIGURE 7-E. Isopleths of normalized ground-level concentration for Trial 11 of the 1974 Fort Huachuca Trial Series.

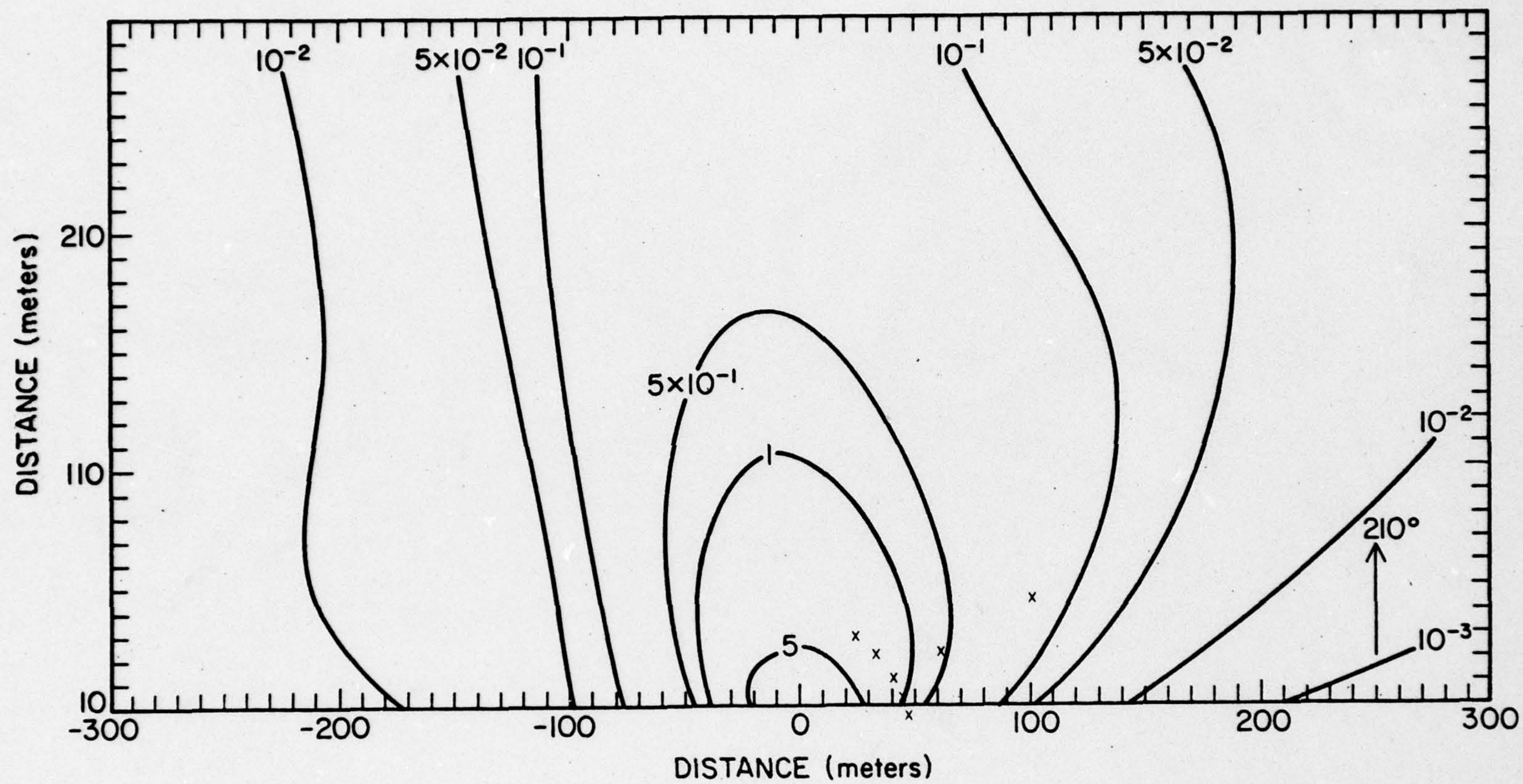

FIGURE 8-E. Isopleths of normalized ground-level concentration for Trial 12 of the 1974 Fort Huachuca Trial Series.

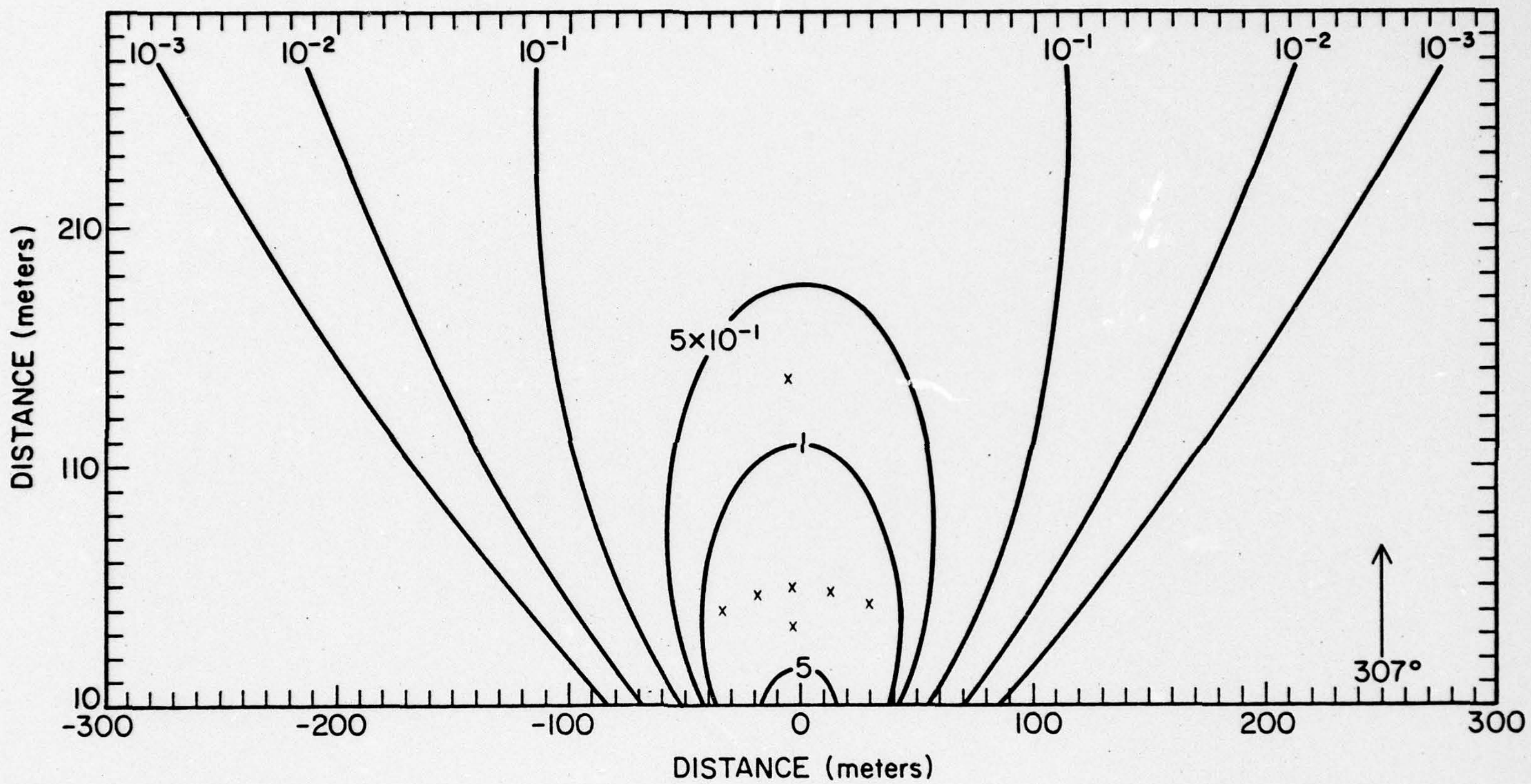

FIGURE 9-E. Isopleths of normalized ground-level concentration for Trial 16 of the 1974 Fort Huachuca Trial Series.

APPENDIX F

NORMALIZED CONCENTRATION ISOPLETH PATTERNS FOR THE 1975 FORT HUACHUCA TRIALS

Computer plots of normalized concentration isopleths for 12 trials of the 1975 Fort Huachuca Trials are presented in this appendix. The abscissa of each plot is lateral distance from the single spray head used in each trial and the ordinate is oriented along the mean wind direction during the sampling period with zero representing the location of the spray head. The arrow in each figure represents the mean wind direction during the sampling period. The small x's show sampler positions. Absolute values of concentration in source units per cubic meter can be obtained by multiplying the values shown in the figure by the source strength of bacteria or dye in source units per milliliter of irrigation water.

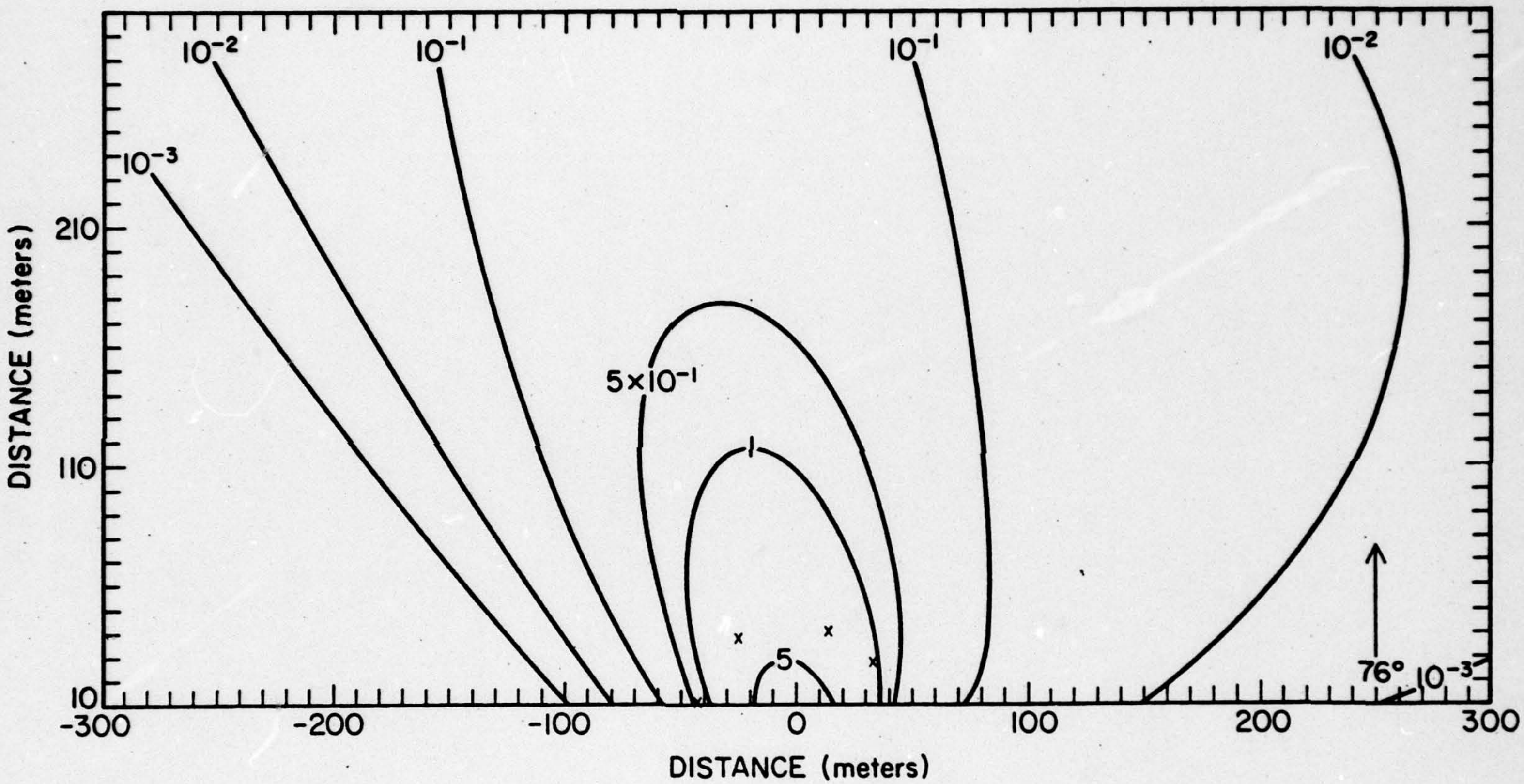

FIGURE 1-F. Isopleths of normalized ground-level concentration for Trial 1 of the 1975 Fort Huachuca Trial Series.

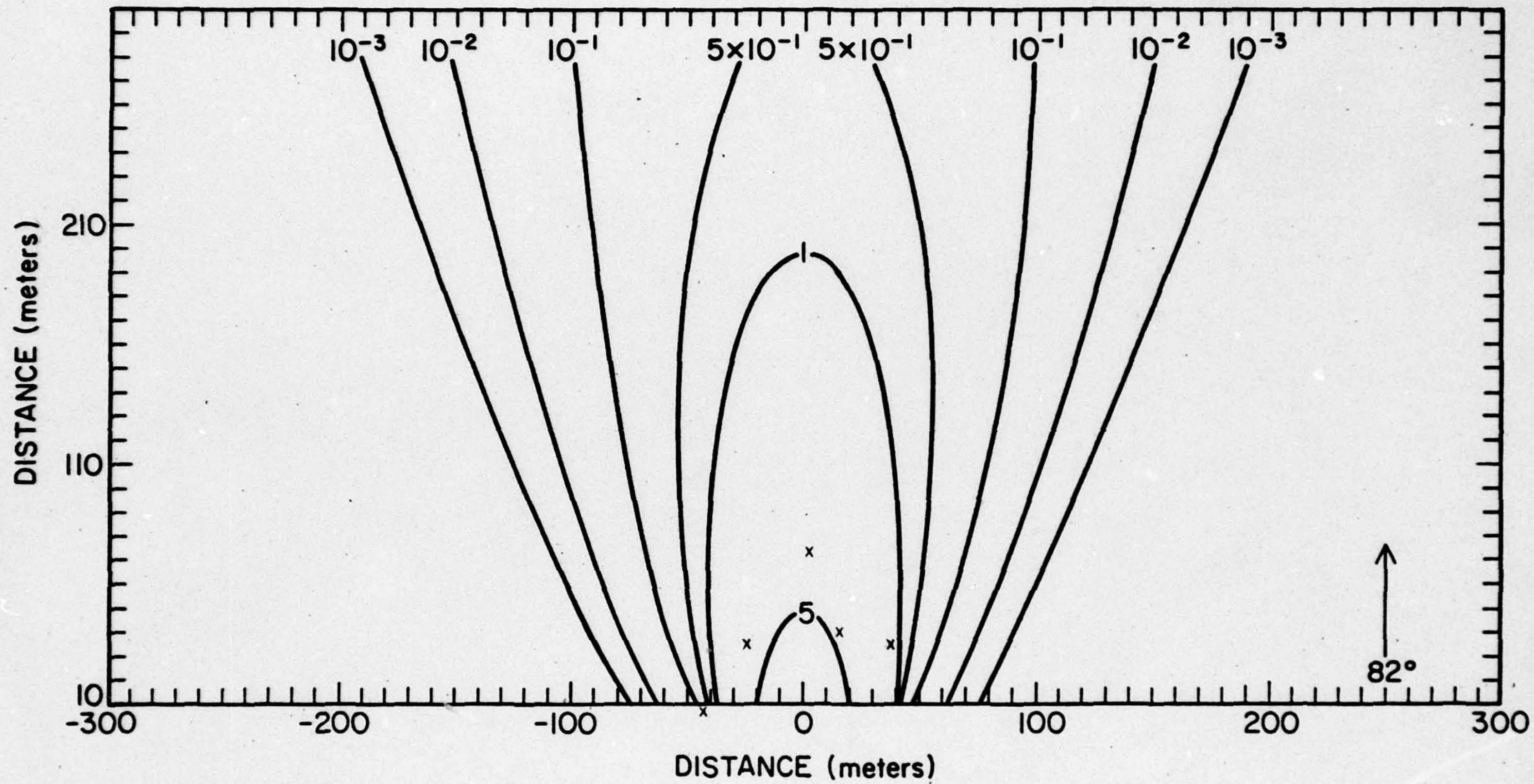

FIGURE 2-F. Isopleths of normalized ground-level concentration for Trial 2 of the 1975 Fort Huachuca Trial Series.

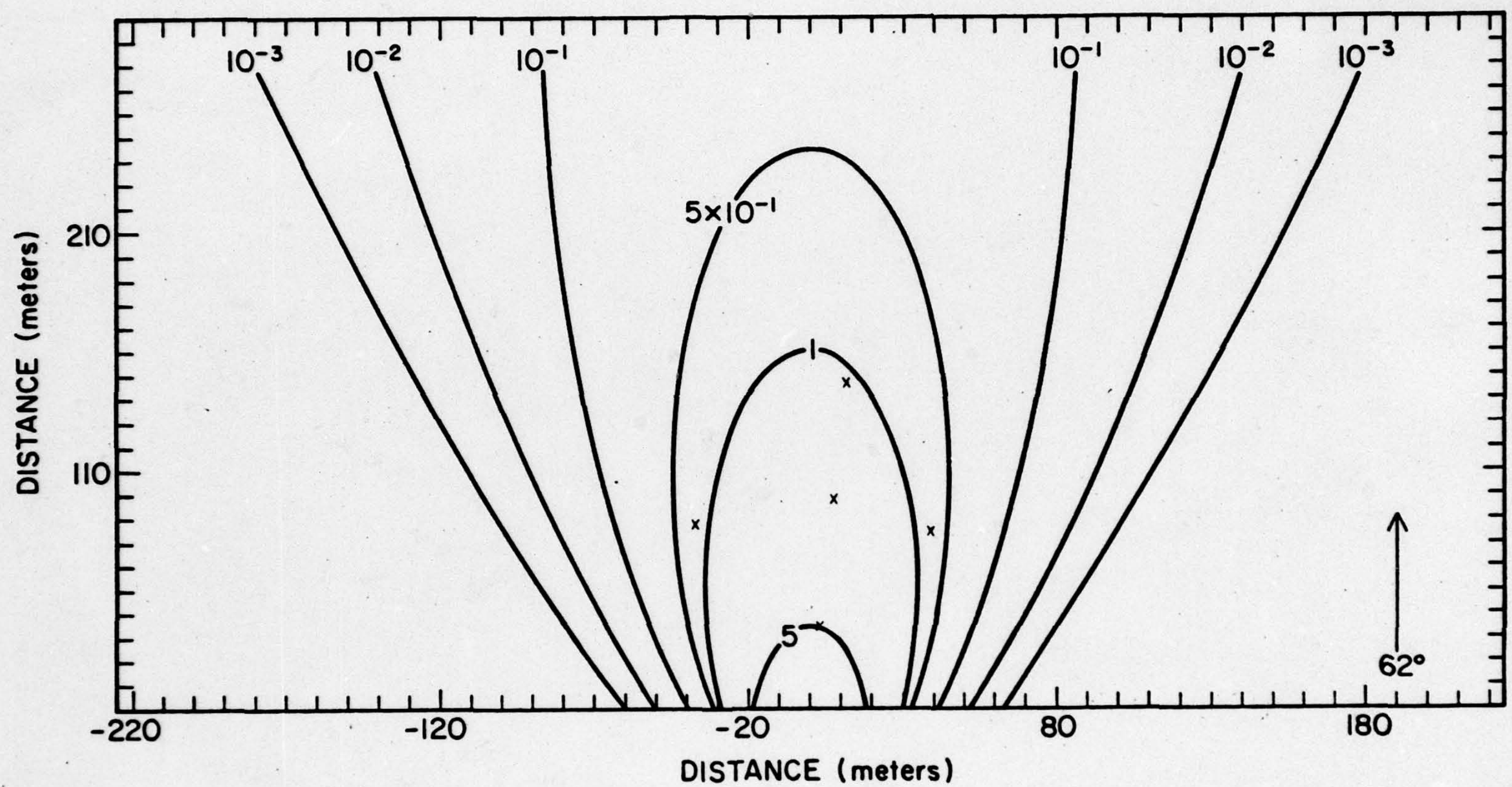

FIGURE 3-F. Isopleths of normalized ground-level concentration for Trial 3 of the 1975 Fort Huachuca Trial Series.

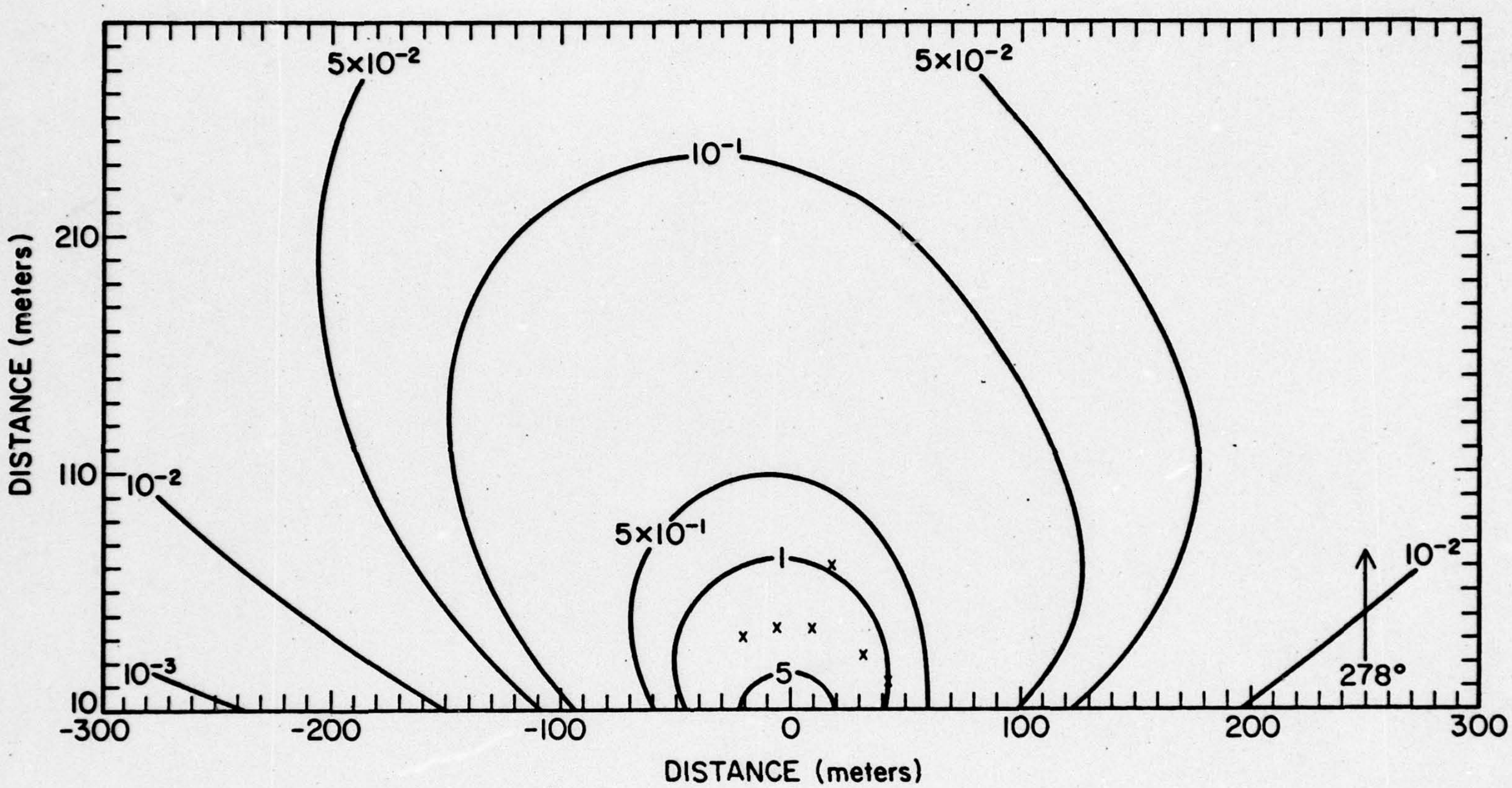

FIGURE 4-F. Isopleths of normalized ground-level concentration for Trial 5 of the 1975 Fort Huachuca Trial Series.

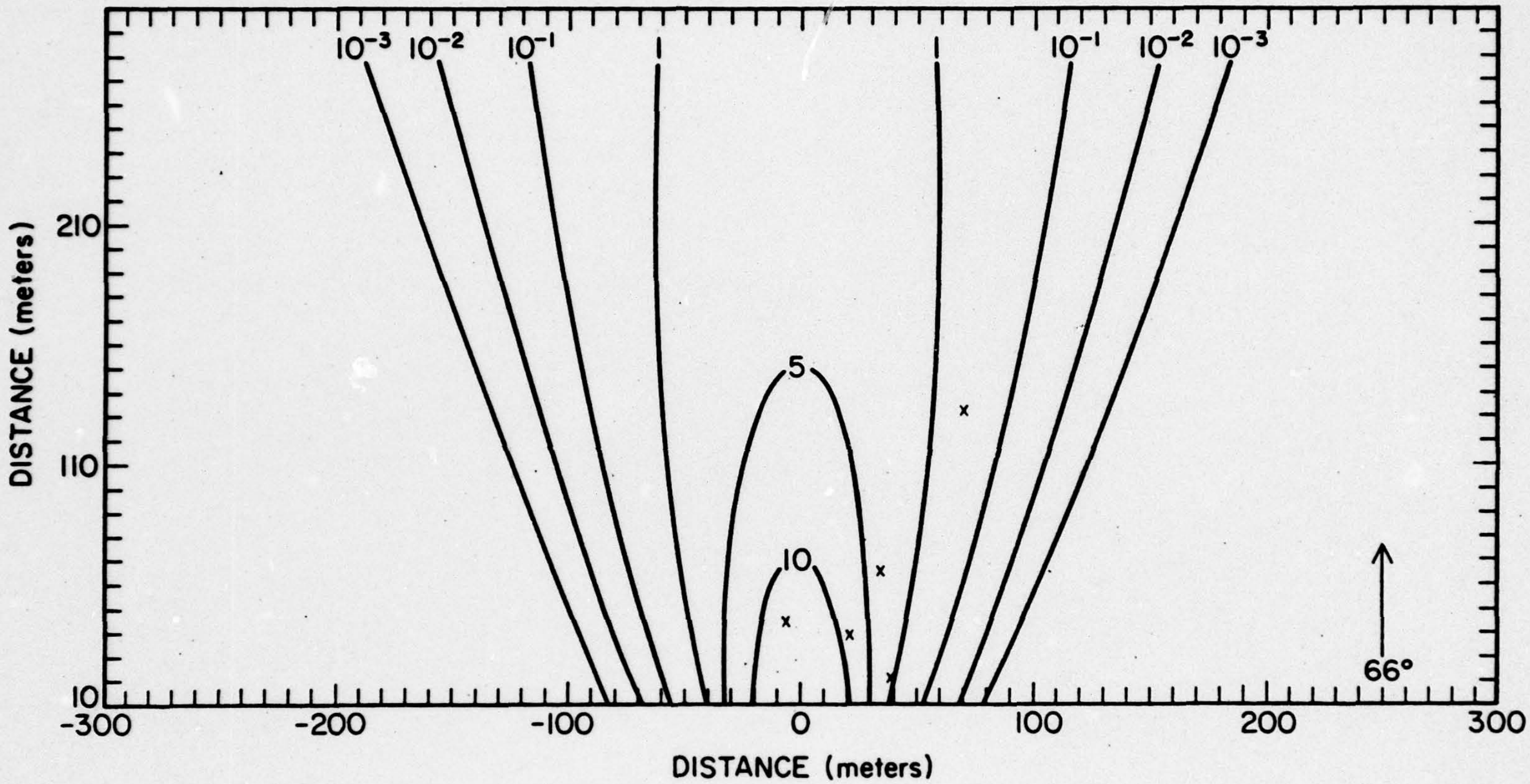

FIGURE 5-F. Isopleths of normalized ground-level concentration for Trial 7 of the 1975 Fort Huachuca Trial Series.

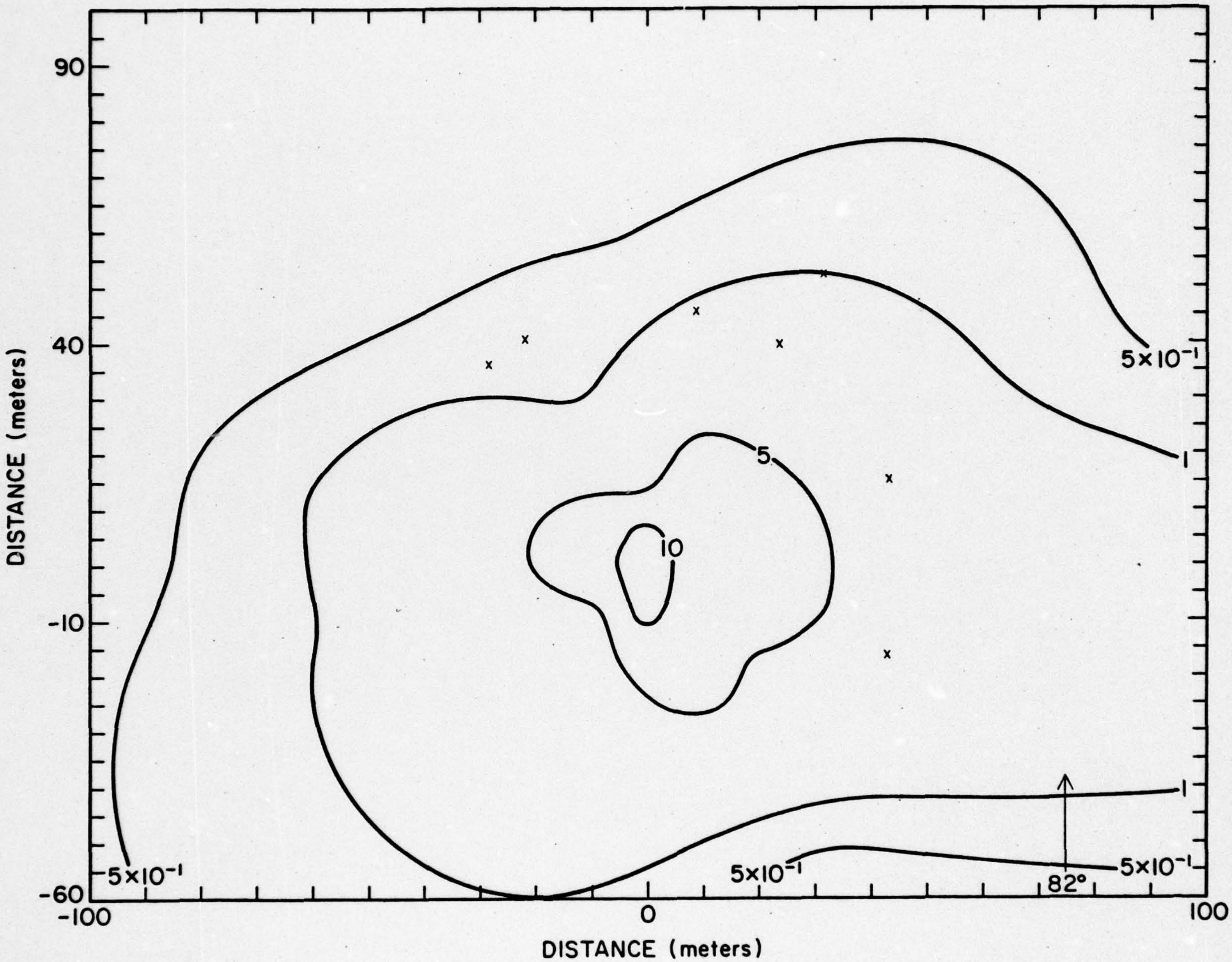

FIGURE 6-F. Isopleths of normalized ground-level concentration for Trial 8 of the 1975 Fort Huachuca Trial Series.

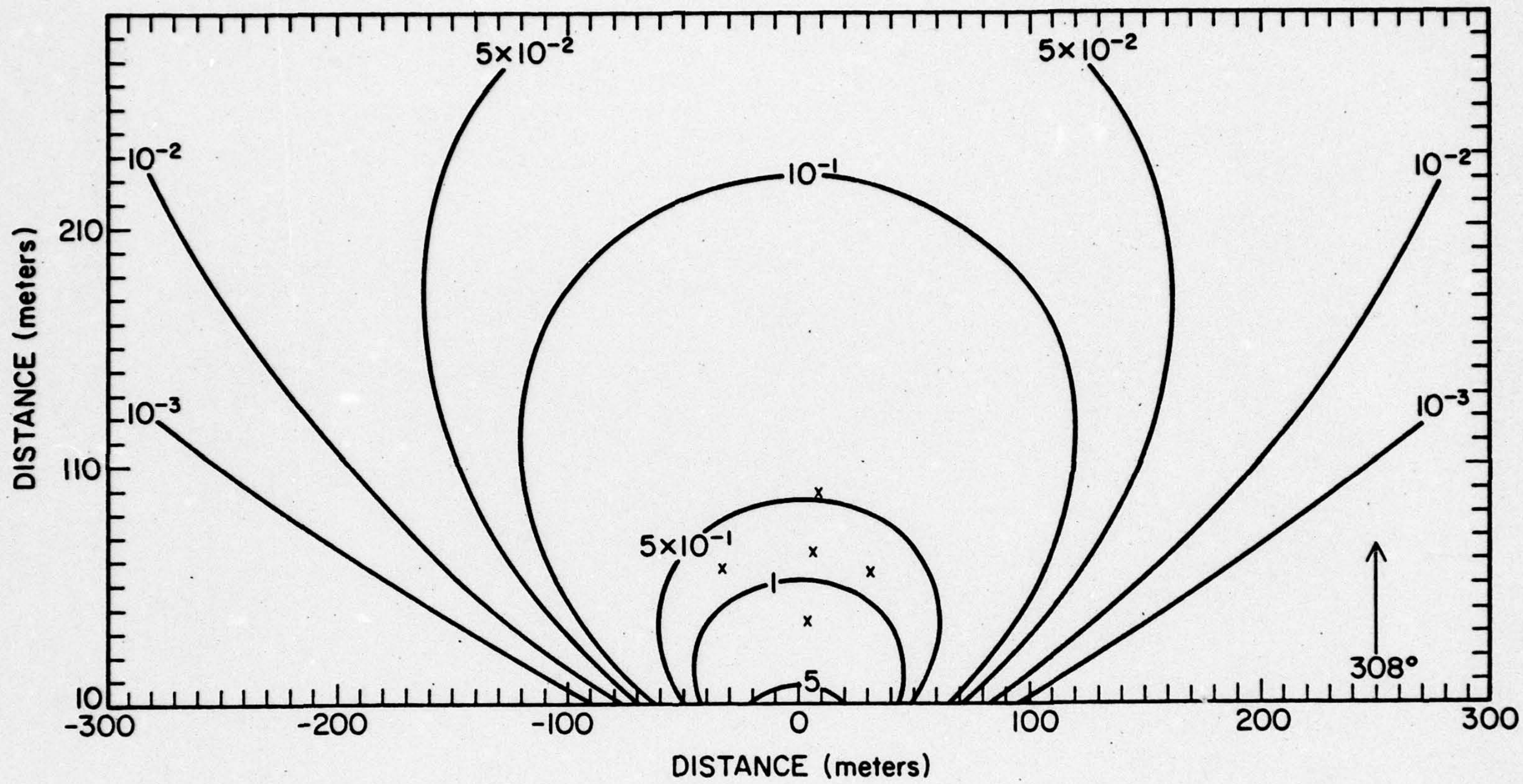

FIGURE 7-F. Isopleths of normalized ground-level concentration for Trial 10 of the 1975 Fort Huachuca Trial Series.

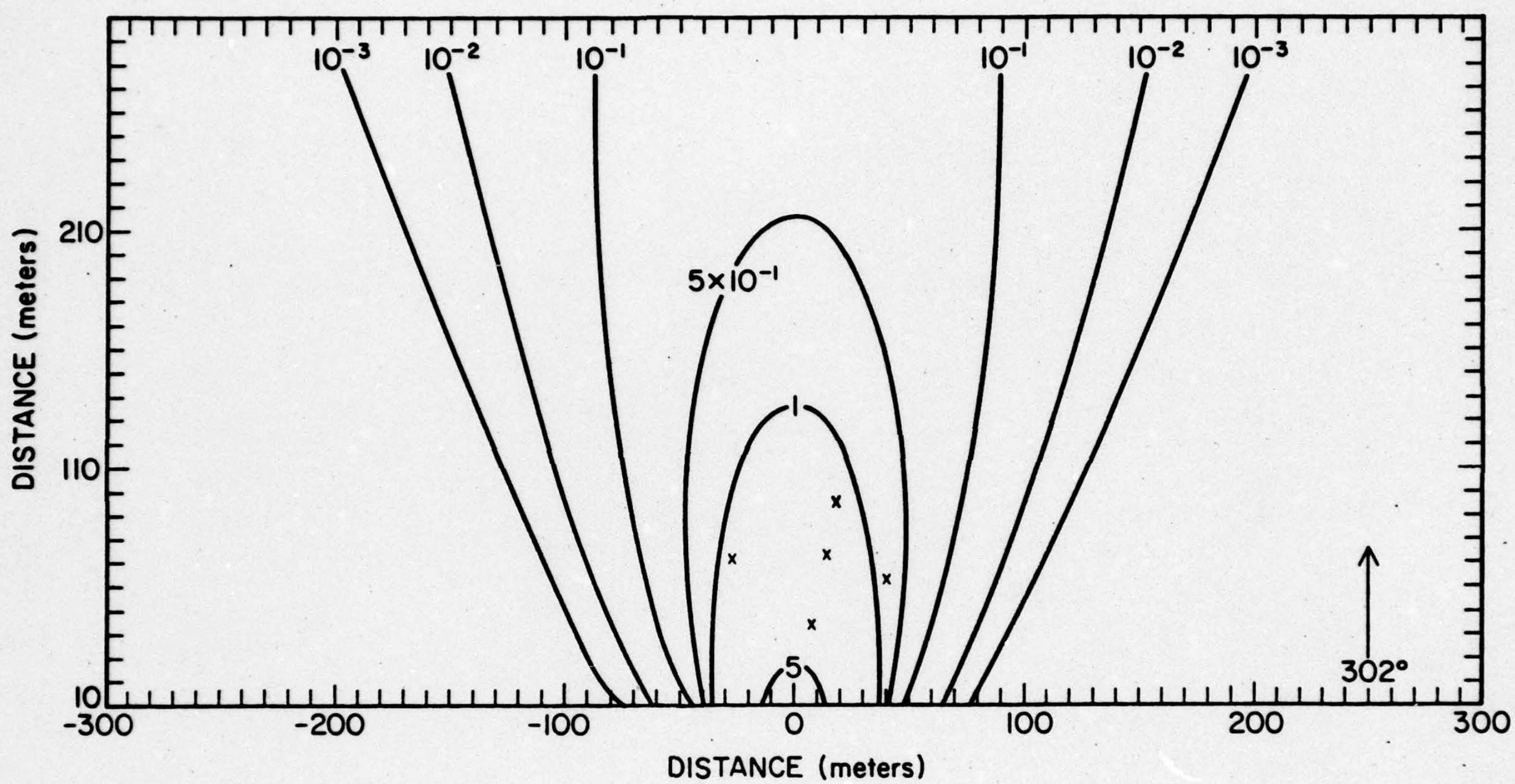

FIGURE 8-F. Isopleths of normalized ground-level concentration for Trial 11 of the 1975 Fort Huachuca Trial Series.

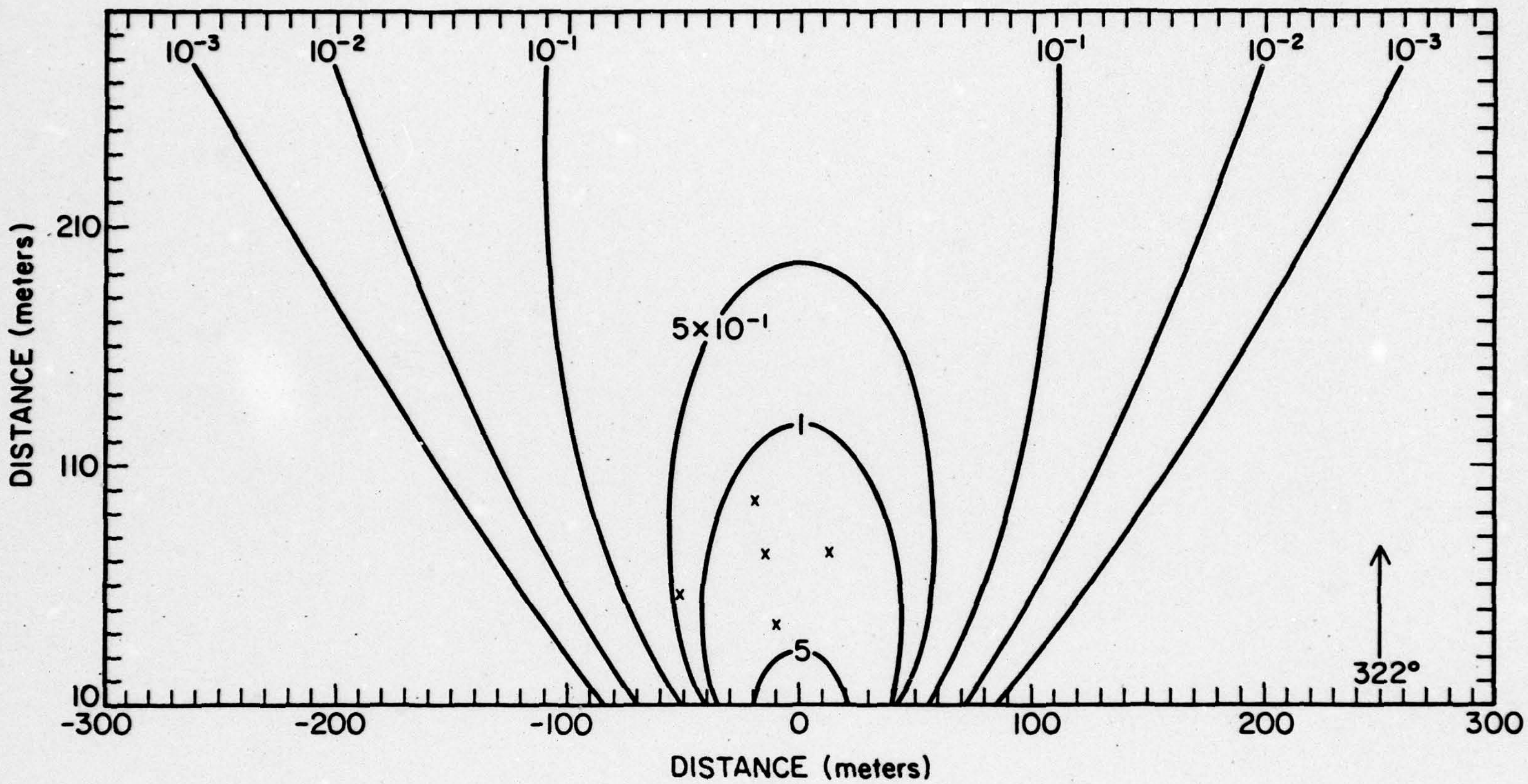

FIGURE 9-F. Isopleths of normalized ground-level concentration for Trial 12 of the 1975 Fort Huachuca Trial Series.

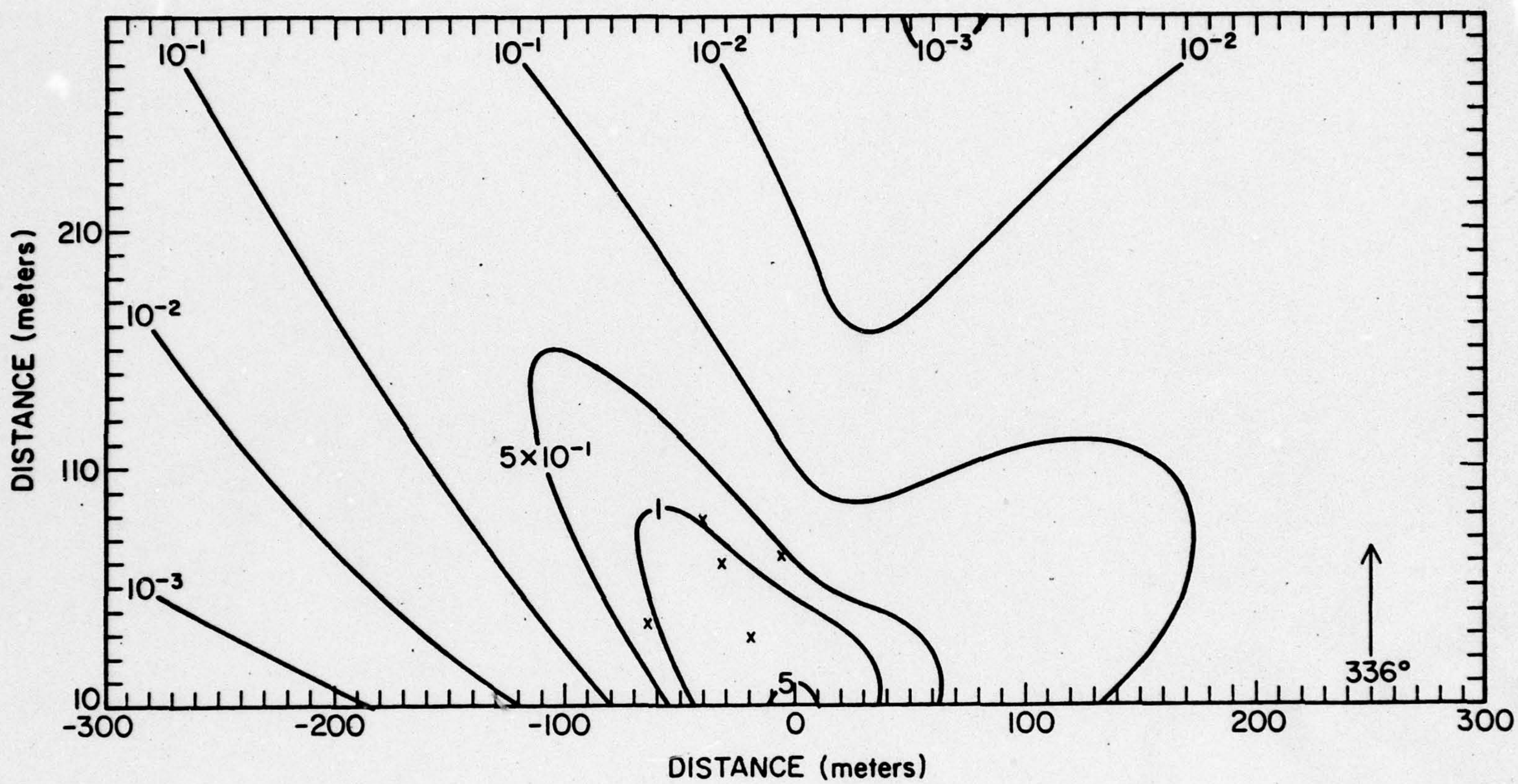

FIGURE 10-F. Isopleths of normalized ground-level concentration for Trial 13 of the 1975 Fort Huachuca Trial Series.

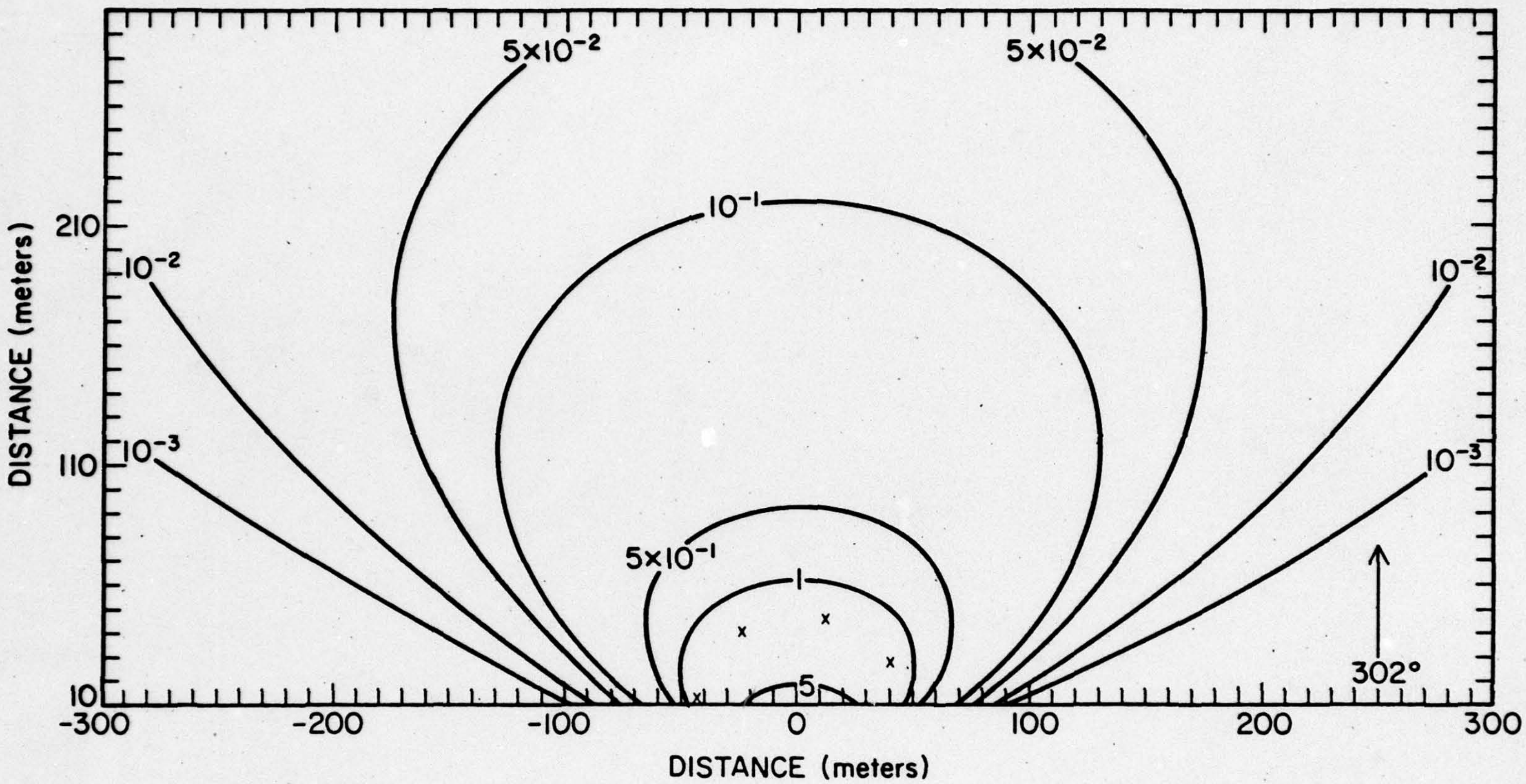

FIGURE 11-F. Isopleths of normalized ground-level concentration for Trial 16 of the 1975 Fort Huachuca Trial Series.

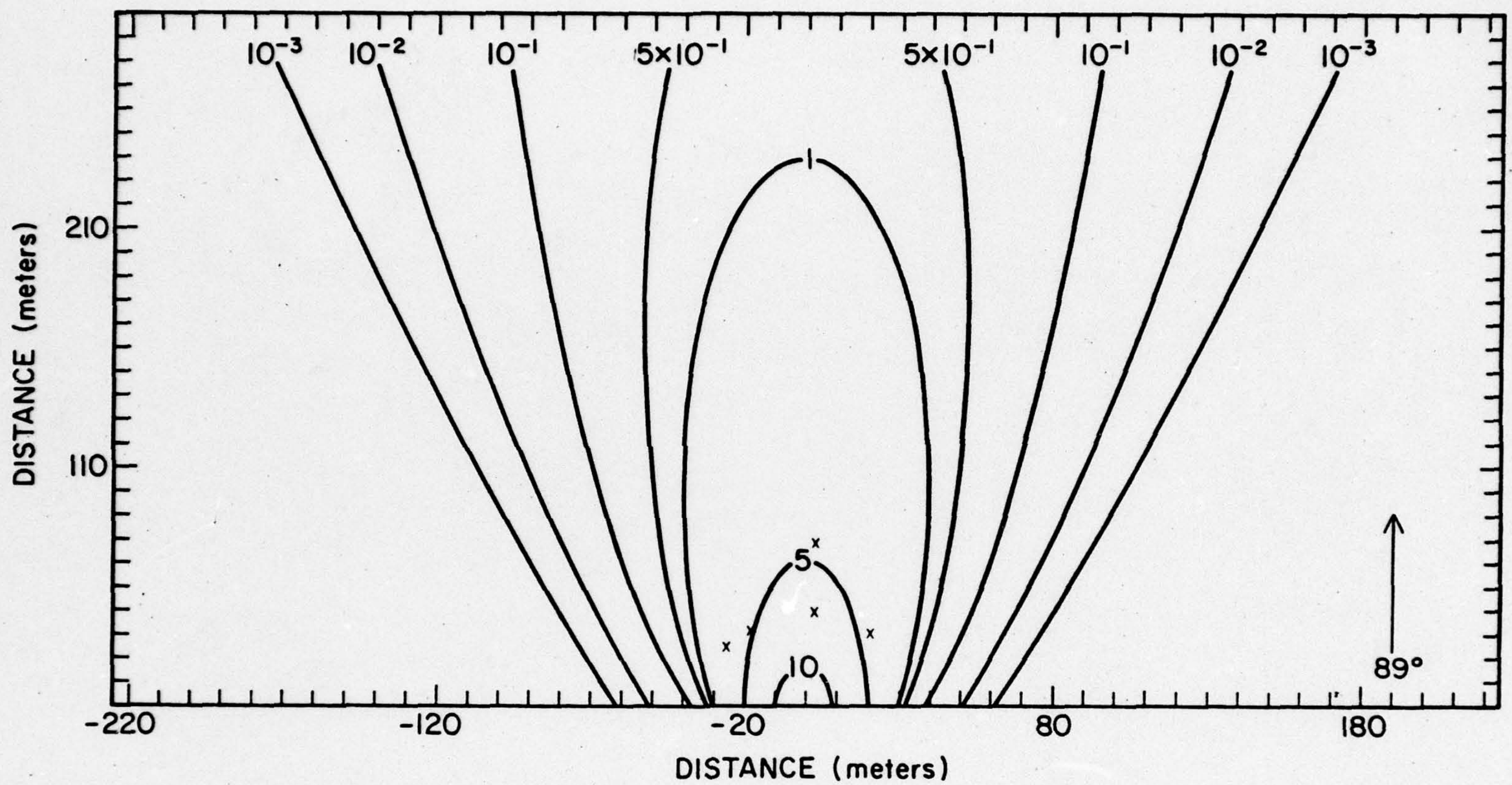

FIGURE 12-F. Isopleths of normalized ground-level concentration for Trial 17 of the 1975 Fort Huachuca Trial Series.

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